NEW ENGLAND WATER WORKS ASSOCIATION.
ORGANIZED 1882.

Vol. III. Sept. 1888. No. 1.

This Association, as a Body, is not responsible for statements or opinions of any of its members.

PROCEEDINGS OF THE SEVENTH ANNUAL CONVENTION,

Providence. R. I., June 13th, 14th and 15th, 1888.

One hundred and eleven members and guests registered at the office of the Secretary, at the Narragansett Hotel. The sessions of the convention were held at the Veteran Firemen's Association Hall, and the exhibits of the Associate Members were displayed in a room beneath the hall.

WEDNESDAY, JUNE 13TH, 1888.

AFTERNOON SESSION.

The convention was called to order at 2.30 P. M. by President Darling. The President introduced Hon. Gilbert A. Robbins, Mayor of Providence, who addressed the convention as follows :

ADDRESS OF WELCOME BY MAYOR ROBBINS.

Mr. President and Gentlemen of the New England Water Works Association:— The city of Providence is always pleased to welcome within its borders strangers or visitors from whatever direction they may come, and I as its representative, extend to you a most hearty greeting to this hall and to this city. As I understand your organization, it represents an enterprise that enters largely into the development and the prosperity of our country, and it is one in which our city is deeply interested. We have grappled with our water works problem, and we think we have as good a system now as there is in this country. We are glad that you are here, and we are glad to have an opportunity to show you what we have got. Our city extends to you a cordial invitation to visit all parts of our water works. We did intend to take you to the new reservoir which we are building, but I understand from your President that your time will not permit. Therefore the Board of Public Works will escort you to our Sockanossett station and to our Hope Street pumping station, and to such other places as you may desire to visit. Our City Engineer, also desires me to extend you an invitation to visit the departments in the City Hall; and the Chief Engineer of the fire department will be pleased to exhibit to you the workings of our hydrants. It gives me pleasure person-

ally to invite you to the City Hall and to the many places of interest in our city. We are an old city. We have lately celebrated our 250th anniversary, but we are not yet complete. We are in the age of progress, and we are trying to make our city what it should be as the second city of New England, as it is to-day. We will be proud to show whatever we have, and I am glad that you are here with us. I trust your stay will be pleasant, that your meetings will be harmonious, and that hereafter, when you think over your annual meetings, the one in Providence will be brightest and greenest in your memory. [Applause.]

After thanking Mayor Robbins in behalf of the convention for his cordial greeting, the President addressed the convention as follows :

THE PRESIDENT'S ADDRESS.

Gentlemen of the New England Water Works Association :—We are to be congratulated upon the number in attendance on this, our Seventh Annual Convention, and also upon the circumstance of holding our meeting in this grand old city of Providence, a place of historical renown. It was to this place that Roger Williams, fleeing from religious persecution in other lands, found his way, founding the city of Providence and establishing the colony of Rhode Island ; here many of the largest industries of New England were planned and carried into effect ; here George H. Corliss, a man who had no peer, erected his plant and manufactured engines which are the admiration of the world ; here, also, you will feel that good old Puritan hospitality extended with words of welcome and good cheer. And while we are here to-day let us remember that this city is bounded on the north by the city of Pawtucket, which also has its fund of historical reminiscences, and which joins in extending a warm welcome, for the two cities are so closely connected it is difficult to discern when you are out of one and in the other. And I might add that the two cities are mutually inclined to work harmoniously in their respective departments, especially in the fire department, where, on more than one occasion, in cases of most serious emergency both cities have rendered valuable assistance. The fact of our meeting in this hall of antiquity must be to us all a pleasure and gratification. Its walls hung with emblems of old times, it carries some of us back to the days when we run with the machine. Later on came the fire engines known as the Amoskeag, Jeffers and Cole, with others. Now we see in many cities and towns only the hose cart and ladder truck, which, when the alarm of fire is given, come rattling down the street and attach to a hydrant, that never gets tired but keeps up a constant stream of water without the use of coal, or men on the brakes. And let me add here that the water and fire departments of every town and city should always work in unison to produce results which both are personally interested in.

We are also to be congratulated upon the rapid growth of our Association ; beginning with a few members we now number 238, which number includes experts on all questions liable to be developed in our discussions. Our meetings during the past year have been of an unusually interesting nature, and intricate subjects have been made so plain that the "ordinary" mind could easily comprehend them.

Our Association is founded on the idea of the interchange of the results accomplished by the various methods employed in cities and towns. Persons uninformed on such matters naturally presume that all water works are alike, but you gentlemen are aware of the difference, and therefore, in assembling as we do and discussing the different methods of management and construction our minds are improved and we are better educated for the performance of our duties.

The great question of the future in this country is that of pure water, and it behooves us to endeavor to discover and pursue a line of thought and study that will transmit to our successors ideas tending to preserve the purity of our streams, especially in New England.

There are other questions of a hydraulic nature which, in our different systems produce results of great importance and untold benefit when developed in a practical manner and communicated in these meetings.

Sanitary questions have been introduced and discussed, and during the past year experts have given us the benefits of intelligent and thorough research on this subject of the greatest concern to the health of populous districts. In fact, any and all subjects in regard to which information was desired have been considered. I am happy to say that the interchange of sketches is growing in favor, a fact which will amply repay our former committee which so earnestly advocated them. Our journal, issued quarterly, is, I am told, meeting with grand success, some gentlemen joining the Association in order to derive the benefits of that alone, who will occasionally meet with us in convention. The editors are entitled to credit for their valuable work.

I think there is a desire among all the members to make the Association what it was intended to be, namely: a social exchange of practical results and not an advertisement for themselves; excepting only our associate members, who, I am pleased to say, make an exhibit of their different devices with an energy and sociability only equalled by their persistency, *in some cases*, in making their goods so desirable and attractive that one can hardly refrain from buying.

The Association, financially, is in good standing, and I trust we shall keep it so, for you all have observed that any concern that has a good balance in the treasury, with no unpaid bills, stands well in the community.

In conclusion. I cannot help speaking of our associates who have passed away.

Phineas Sprague, died September 14, 1887.
Thomas A. Hodge, died December 16, 1887.
Hosea H. Whidden, died January 31. 1888.
Sylvanus D. Horton, died April 19, 1888.
Albert D. Upton, died January 8, 1888.

All men of true worth, social, courteous and affable, and the positions they held showed the confidence that was reposed in them by their fellow townsmen.

Mr. Horton was my associate in business for the past twenty-five years, and I mourn his loss like a brother and lifelong friend.

[Applause.]

At the close of the President's address the convention proceeded to the regular order of business. On motion of Mr. Grannis the reading of the records of the last meeting was dispensed with.

ELECTION OF MEMBERS.

The President announced the next business in order to be the consideration of applications for membership.

The Secretary presented the following list of applications for membership, all of which had been considered by the Executive Committee and approved :

RESIDENT ACTIVE.

Albert S. Burnham, Superintendent, Revere, Mass.

H. S. Chase, Superintendent, Great Falls Manufacturing Company, Great Falls, N. H.

Thomas M. Drown, Professor of Chemistry, Institute of Technology, Boston.

Parker Merrill, Superintendent, Melrose, Mass.

J. Herbert Shedd, Civil and Hydraulic Engineer, Providence, R. I.

Fred. A. Volk, Superintendent, Ware, Mass.

George F. Chase, Superintendent, Taunton, Mass.

F. H. Crandall, Superintendent, Burlington, Vt.

NON-RESIDENT ACTIVE.

W. B. Cunningham, Superintendent, Trinidad, Colorado.

James Davidson, Superintendent, Central City, Colorado.

Henry M. Newton, Superintendent, East Saginaw, Mich.

Lewis H. Pengilly, Civil Engineer, Tuxedo Park, N. Y.

J. W. Troy, Superintendent, Pierre, Dakota.

Timothy Woodruff, Superintendent, Bridgeton, N. J.

Charles E. Bolling, Superintendent, Richmond, Va.

Heland C. Hitchcock, Treasurer, Addison, Steuben County, N. Y.

ASSOCIATE.

Fred. Adee & Co., Plumbers' Supplies, 90 Beekman Street, New York City.

H. R. Barker Manufacturing Company, Pipe, Supplies and Fittings, Lowell, Mass.

H. M. Brewster, Manager, E. Stebbins Manufacturing Co., Brightwood, Springfield, Mass.

Jarvis B. Edson, Recording Gauges, 145 Broadway, New York City.

The Jackson & Woodin Manufacturing Company, Cast Iron Pipe, Berwick, Pa.

Benjamin S. Terry, A. W. Harris Oil Company, Providence, R. I.

The Water Waste Prevention Company, Water Meters, 143 Nassau Street, New York City.

George Ross, Ross Valve Co., Troy, N. Y.

William Oliphant, Filters, 112 Liberty Street, New York City.

On motion of Mr. Fuller, the Secretary cast the ballot of the Association for all the applicants and they were declared elected.

The Secretary read the

REPORT OF THE SECRETARY.

R. C. P. COGGESHALL, SECRETARY.

IN ACCOUNT WITH THE

NEW ENGLAND WATER WORKS ASSOCIATION.

DR.

To amount received as follows :		
From initiation fees,	$ 377.00	
" dues,	535.50	
" sale of transactions,	42.80	
" advertising,	1,035.00	
		$1,990.30

CR.

By amount paid Albert S. Glover, Treasurer.	$1,990.30

Respectfully submitted,

R. C. P. COGGESHALL, Secretary.

New Bedford, Mass., June 12, 1888.
Accepted and placed on file.

The Treasurer stated that the amount in the treasury above all liabilities was $888.31 and submitted the

REPORT OF THE TREASURER AND FINANCE COMMITTEE.

ALBERT S. GLOVER, TREASURER,

IN ACCOUNT WITH THE

NEW ENGLAND WATER WORKS ASSOCIATION.

1887.	DR.		
Aug. 1.	Received from Albert S. Glover, Secretary, sundry amounts collected by him as follows :		
	For membership dues,	$63.00	
	For advertising dues,	50.00	
	For Subscription dues,	6.00	
	For transactions sold,	4.00	
			$123.00
"	Received from Edwin Darling, retiring Treasurer,		$472.16
"	" " R. C P. Coggeshall, Secretary.		94.90
Aug. 31,	" " " " "		50.00
Sept. 20,	" " " " "		300.00
Oct. 20,	" " " " "		260.00
Dec. 13,	" " " " "		350.00
1888.			
Mar. 7.	" " " " "		300.00
May 12	" " " " "		115.00
June 12	" " " " "		520.40
	Total receipts,		$2,585.46

1887.	Cr.	
July 26.	Paid J. P. Bacon, Stenographer,	$101.25
Aug. 1.	" Edwin Darling, for amount disbursed by him to John S. Sampson,	94.50
Aug. 31.	" Newton Graphic Printing,	3.25
Sept. 1.	" Albert S. Glover, for sundry amounts disbursed by him,	12.13
" 1.	" J. C. Clark Printing Company, printing,	4.25
" 1.	" Rand Avery Co., printing,	3.00
" 2.	" " " " "	5.50
" 2.	" C. H. Stacy, postage, etc.,	14.43
1888.		
Jan. 6.	Paid Jas. P. Bacon, Stenographer,	18.00
" 11.	" R. C. P. Coggeshall, for Association meeting expenses,	11.00
" 12.	" Newton Journal, printing,	1.75
" 12.	" J. C. Whitney, clerical work,	4.12
Feb. 16.	" Young's Hotel, Association meeting expenses,	6.50
" 21.	" John S. Sampson, printing, etc.,	50.00
Mar. 9.	" R. C. P. Coggeshall, salary for three months,	75.00
" 9.	" R. C. P. Coggeshall, for sundry disbursements made,	53.37
" 15.	" Young's Hotel, expenses at Association meeting,	9.60
" 29.	" Jas. P. Bacon, Stenographer,	20.75
Apr. 13.	" John S. Sampson, printing.	102.80
1887.		
Sept. 21.	" John S. Sampson, printing,	268.65
" 21.	" Forbes Lithographic Co., "lithos,"	33.76
" 29.	" Benjamin Grey, flowers,	10.00
" 21.	" R. C. P. Coggeshall, for sundry disbursements made,	52.15
" 21.	" R. C. P. Coggeshall, salary for three months,	75.00
Oct. 21.	" Edwin Dews, stationery, etc.,	24.65
" 21.	" Forbes Lithographic Co., "lithos,"	105.98
Dec. 14.	" Heliotype Printing Co., heliotypes,	46.50
" 11.	" R. C. P. Coggeshall, for amount expended for Association meeting,	11.00
" 14.	" John S. Sampson, printing,	122.35
" 14.	" R. C. P. Coggeshall, salary for 3 months and incidentals,	89.58
" 15.	" Wm. R. Billings, postal cards,	4.50
1888.		
June 4.	" Collins & Fairbanks, badges,	16.25
" 12.	" R. C. P. Coggeshall, Secretary, salary to June 15,	75.00
" 12.	" R. C. P. Coggeshall, Secretary, for disbursements for postage, etc.,	23.76
	Total payments,	$1,550.33

Recapitulation.

Receipts,	$2,585.46
Payments,	1,550.33
Balance on hand,	$1,035.13*
From this amount should be deducted bills payable	146.82
Leaving in treasury above all liabilities,	$888.31

*Of this amount there is deposited in Providence County Savings Bank, Pawtucket, R. I.,	$472.16
In Citizen's National Bank, New Bedford,	520.40
In First National Bank, West Newton,	42.57
	$1,035.13

Respectfully submitted,

ALBERT S. GLOVER, Treasurer.

Approved, Geo. E. Batchelder, for Committee.

The President stated that the report of the Committee on Badges would be passed, and that the next business in order was the nomination of officers for the ensuing year.

On motion of Mr. Walker, (amended by Mr. Glover,) the President was directed to appoint a committee of five, to submit a list of nominations. The President subsequently named the following committee: Charles K. Walker, of Manchester, N. H.; Willard Kent, of Woonsocket, R. I.; David B. Kempton, of New Bedford, Mass.; Albert F. Noyes, of West Newton, Mass., and Joseph G. Tenney, of Leominster, Mass.

Phineas Ball, Civil Engineer, of Worcester, Mass., read a paper on "Soils from which water supplies may be drawn by filter galleries or driven wells," which was discussed by Messrs. Fuller, Winslow, Rice, Noyes and Tidd.

The President appointed Messrs. Sherman and Richards a committee to distribute sketches, and the Secretary read the following letters:

AN APPEAL FOR AID.

PHILADELPHIA, PA., June 5th, 1888.

MR. R. C. P. COGGESHALL,
Secretary New England Water Works Association,
New Bedford, Mass.

Dear Sir:—Mr. Rudolph Hering and myself, who are preparing a translation of Kutter's "Versuch," giving the development of the celebrated "Kutter's Formula" for flow of water in open channels, are desirous of issuing a circular to the profession, and to hydraulic engineers in particular, calling attention to the sad fact stated in "Engineering News" of 26th ult., that Mr. Kutter, who died May 6th, left a widow and children without means; and I venture to ask that you will send me a list of the members of your Association.

We should be greatly indebted also if you would kindly bring the matter to the attention of the Association as a body.

I called upon Mr. Kutter at his home in Berne, last December, and found him a feeble old man, exceedingly modest, and living in the plainest way. I am satisfied that any subscriptions sent to "Engineering News" for this cause will be well bestowed.

In view of Mr. Kutter's great service to the profession, it seems but fair that some such acknowledgment should be made.

Yours truly,

JOHN C. TRAUTWINE, JR.

Referred to the Executive Committee.

AN INVITATION FROM THE CITY ENGINEER.

CITY ENGINEER'S OFFICE, CITY HALL, PROVIDENCE, R. I., July 13, 1888.

EDWIN DARLING, ESQ.,
President New England Water Works Association.

Dear Sir:—The City Engineer extends a cordial invitation to the New England Water Works Association to visit the City Engineer's office during their visit in this city.

Yours respectfully,
SAMUEL M. GRAY,
City Engineer.

A general description of the Providence Water Works by the City Engineer was distributed.

AN INVITATION FROM THE MAYOR OF CAMBRIDGE.

MAYOR'S OFFICE, CITY HALL, CAMBRIDGE, June 13, 1888.

NEW ENGLAND WATER WORKS ASSOCIATION.

Gentlemen:—By unanimous vote of the City Council of Cambridge, it gives me much pleasure to extend to you a cordial invitation to visit this city on your annual field day, next fall, and to accept her hospitality during your visit. We shall take much pleasure in showing you our system of water works and its recent extension, and other matters of interest here, and we will make every effort to have your visit here as pleasant to you as it will be to us.

I am very truly yours,
WILLIAM RUSSELL,
Mayor.

On motion of Mr. Billings it was :

Voted : That the kind and courteous invitation of the Mayor of Cambridge be accepted.

Mr. W. P. Whittemore, Superintendent, North Attleboro, Mass., read a paper entitled "High Water Alarm for reservoirs and tanks" which was discussed by Messrs Rice, FitzGerald, Tidd, Fuller, Darling and Tilden.

The President announced that arrangements had been made for an excursion down the river on Friday and a Rhode Island clam-bake at one of the shore resorts, and called attention to the understanding had at the meeting in Manchester last year, that the expenses would be borne by the individual members participating in the festivities. A suggestion was made that the Association charter the boat, paying therefor out of the funds in the treasury, but the President ruled that such an expenditure of the Association's money would be unconstitutional. In response to a request that those members present who intended to make the excursion should rise, a sufficient number rose to warrant the chartering of the steamer.

THE USE AND WEIGHT OF SPECIAL CASTINGS.

The President announced the first topic for discussion as "What is the best way to limit the use and weight of special castings," and called on Mr. Tidd to open the discussion.

Mr. Tidd. I did not come prepared to make any special remarks upon this subject, still I think it is one of some importance. I have an instance in mind now where we are using pipe cast in Scotland, where, in issuing my specifications, I called for the weights and lengths of pipe and the thicknesses the same as we have them here in our own foundries. The founders agreed to cast them to the length which I required, and to the sizes. They telegraphed very early, for fear the steamer might not bring the bid soon enough, and were the lowest bidders, but when the formal bid came it gave increased weights. The Commissioners thought that even then they were somewhat lower than the others, and they finally closed the contract. Then the founders wanted to make them nine feet in length, adding thirty-three per cent. more bells and joints, and furthermore they complained that the pipe would not stand the required test of 300 pounds to the square inch, being thinner than those used for gas pipes. All these objections were made after the contract had been awarded to them. The Commissioners submitted the case to me, and I told them either to make them do as they agreed to or get out. But the Commissioners were somewhat alarmed for fear they might lose their contract, having released the other bidders, and they submitted, and now the founders have delivered specials of great weight. In this case I sent the drawings for the specials I wanted, and I instructed my assistant if the castings exceeded the weight I had ordered to condemn the whole of them. I know it is customary to put all the iron possible into specials, because they are limited on the straight pipe and cannot exceed a fixed quantity. My impression is the best way for us to do is to limit the weights of the casting to the drawings given, the same as we do the pipe, and either take them without payment for all over, or else condemn them. I propose to do so in the future. I am very much in favor of the Globe special. Their style of castings is one which will allow of light weight without danger to the strength of the casting. I have ordered many of these castings lately and I like them very much, and I hope ultimately to use them wherever I can.

Mr. FitzGerald. I suppose this subject may be connected more or less with the subject of the depth of the bells. I believe the city of Boston has always stood by its old depth of bell, five inches, which enables them to go around a great many corners without specials, and to do a good many things they could not do with a shorter bell. I should like to hear from some members who are connected with works where they use shorter bells, as to whether they do not find it necessary to incur a larger expense for special castings. It seems to me that question is more or less connected with the subject under consideration, and that it may be with profit brought into the discussion.

Mr. Tidd. The depth of the bell in a fourteen-inch pipe that I use is about three inches and a half, I think, and I use that largely because I can get around curves easier than I could with a deep bell. If the bells are too deep we get afoul of the edge of the bell before we make much of a curve.

Mr. FitzGerald. Doesn't the use of a short bell limit very much the amount of the lead? Of course the shorter the joint the less lead you have to stand the pressure.

Mr. Tidd. I use two inches and a half of lead.

The President. Under all circumstances?

Mr. Tidd. Under almost all circumstances. In some of the smaller pipes I use two inches and a quarter.

Mr. Noyes. It has been our practice in making drawings to calculate carefully the theoretical weight, then to limit the contractors to four per cent. either way, and then not to accept any castings that are more than four per cent. under the standard weight, and not to pay for more than four per cent. in excess of the standard weight, and we never have had any difficulty. We use in Newton what is known as the Providence bell, and it gives the greatest satisfaction. In regard to the question of using less lead, we do it as a matter of economy. The bell, as you know, gives a wedge of extra thickness of lead the whole length of it, and in the Boston bell there has seemed to me to be a defect in that respect. For instance, the little circular rim, which it seems to me in corking you are apt to cork by, and the area of lead is so slight it is liable to be blown out. I will say that so far as we can judge the leakage on our works is probably very nearly if not quite as low as on most any works, and I think it is largely due to the tightness of the joints.

Mr. FitzGerald. What is the depth of the bell?

Mr. Noyes. It is two and one-quarter and two and one-half inches, according to the different sizes; they vary a little, the large sizes being a little more than the small ones. In reference to the use of specials, I would say that we stake out a transit line, and then we have regular rules by which there is no deflection of a single line of pipe allowed above a certain number of degrees. We have what we call a special, which is a sixty-fourth, a thirty-second, a sixteenth, an eighth and a quarter bend; and in all cases the assistants are instructed not to call for these specials unless the deflection is above a certain degree.

Mr. Rice. I didn't understand what you said your depth of bell was.

Mr. Noyes. If I recollect it is either two and one half or two and one quarter, and it may be two and one-eighth.

Mr. Rice. Do you mean that is the whole depth of the bell?

Mr. Noyes. That is the whole depth of the bell. It is the regular Providence bell. I attribute a good deal of its stability to the solid wedge that you get inside, and to the fact that the lead cannot be forced out. There is no chance for the lead to be corked by, as it seems to me there is in the Boston bell. The lock, of course, secures a greater strength in proportion to the depth of the bell.

Mr. Tidd. It seems to me that the bead in the Boston bell, (which is, I think, about a quarter of an inch high and a quarter of an inch in width,) if the rim is moved at all must necessarily be cut off, and for that reason I always use the wedge such as Mr. Noyes speaks of. And I think that is used in almost all the works I have seen in the last seven or eight years, except in New York, where they have no lock at all, simply a smooth bell. In Halifax, N. S., they wedge them with wood, kiln dried and driven home hard, instead of lead. It makes a good joint, and they say it is very efficient and will last a long while.

Mr. FitzGerald. I should like to ask Mr. Noyes if he ever had any case of a pipe being blown up out of the street.

Mr. Noyes. I don't know of any. From what cause?

Mr. FitzGerald. Very possibly from the water ram.

Mr. Noyes. I never have heard of any and don't think we have had any case of that kind on the works.

Mr. FitzGerald. We had a 48-inch main with a five inch joint blown up in that way, and it has always seemed to me that with a much shallower joint the danger would be greater. I don't know why it should not be, although it may be that this wedge is much more efficient. It is an important subject and one which I hope this Association will investigate at some time or other by a committee.

Mr. Noyes. Such has always seemed to me to be the fact and so far as I have studied it in relation to our works I have been confirmed in my opinion. In reply to the question Mr. FitzGerald asked a moment ago, I know we have at certain parts of our works in operating our pumps a very considerable water ram, in fact so much in some of the services as to burst wrought iron pipe, but I have never known of its having any effect on the water mains.

Mr. FitzGerald. It seems to me that this matter of the relation of joints to the efficiency of the pipe, the method of making the joints, the facility afforded for going around curves and obstacles, and all that, would be an extremely interesting one for this Association to investigate through a special committee.

The President. I am using some 36-inch Globe specials referred to by Mr. Tidd, and the diameter inside is so much larger than the 36-inch pipe that I think it overcomes the friction where you are going to make a curve, or enough of it so that a curve is not required to get around.*

Mr. Tidd. The founders complain in making right angle branches and things of that sort, that it is very difficult to make it of the same thickness and make a good job without filling it in with iron and then rounding it. But, of course, as they make them by the pound or the ton, which is the same thing, I think they are troubled with a little natural human weakness to make all the money they can, and, therefore, are not particular to put in the least possible amount of iron. At the same time, unless the core fits very nicely there will be a sharp fin sticking out on the inside, and the water, instead of being carried ahead, is given a turn as it passes around the bend. Now, in the particular form in which the globe specials are made, the basis of the whole is the globe, which can be easily cast, and the core can be fitted to anything they choose to make. In using that particular form they have a better opportunity to adapt the iron to any thickness they like than they have with the old form, and for that reason they make them almost uniform. You can get them any thickness you like, and the thickness is uniform to the core all through, and, as you say, Mr. President, it gives a larger throat; at least the water has a better passage around the curve in it than around the sharp corners of the other. I have found them preferable to the others, and I propose to use them in the future, unless something better is devised.

Mr. Swan. In regard to the Providence bell, I remember making the

*This special we think has for a 90° bend, a radius of about three-fourths its diameter, which would consume about four and a half times as much head as a bend with a radius of three diameters.—See Civil Engineers' Pocket Book, Trautwine, p. 256. (Editor.)

original drawings in 1870, and the depth of the bell was made dependent on the diameter of the pipe. As I remember the drawings now, the depth of the bell on a six-inch pipe was two inches, and of a thirty-six-inch pipe four inches. The depths were not constant for successive diameters but varied, increasing in a numerical ratio.*

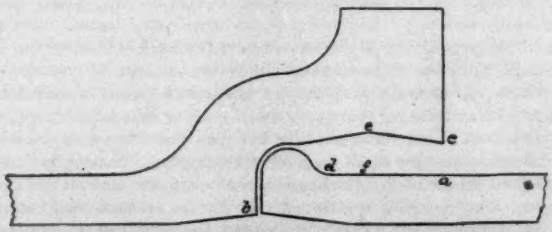
Mr. Noyes. I think we should not drop Mr. FitzGerald's suggestion that the Association appoint a committee to investigate this subject, for it is one of a good deal of importance in several ways. It is estimated that in the construction of the Newton works there was an actual saving of some $14,000 in iron and lead alone, which was quite an item. Of course, that was criticised, or was open to criticism, upon the ground that it might be weakening the works and thereby making liable an increase in the cost of maintenance which would more than equal the saving. But the works have been in operation some twelve or thirteen years, and it seems to me that the results have shown the wisdom of the original conclusions. I hope that a committee will be appointed to look into this matter substantially as Mr. FitzGerald has outlined.

Mr. FitzGerald. I move, Mr. President, that a committee of three be appointed by the Chair to investigate and report in regard to this whole matter of joints and their relation to special castings, and in regard to special castings themselves. Adopted.

Adjourned to 7.30 P. M.

EVENING SESSION.

In the evening Prof. J. E. Denton, of the Stevens Institute of Technology, Hoboken, N. J., addressed the Association on the method of building the new Croton Aqueduct for increasing the water supply of New York city. His lecture presented lantern views of a map showing the location of the new Croton Aque-



*The above cut shows the shape of the Providence bell, the principal dimensions are as follows: Depth of bell (a. b. sketch) 4 in. and 6 in. pipe, 2 in., 8 in. pipe, 2¼ in., 10 in. pipe 2¼ in., 12 in. pipe 2⅜ in., 14 in. pipe 2½ in., 16 in. pipe 2⅝ in., 18 in. pipe 2¾ in., 20 in. pipe 2⅞ in., 24 in pipe 3¼ in., 30 in. pipe 3½ in., 36 in. pipe 4 in. Joint room (a. c. sketch) is 5-16 in. for 4 in. pipe, and ⅜ in. for all other sizes. Thickness of wedge (f. e. sketch) 7-16 in. for 4 in. pipe and ½ in. for all other sizes.

E. B. Weston, C. E. Engineer in charge of the Water Department of Providence who kindly furnished the above data, writes: that his personal experience with 24 and 30 inch pipe leads him to the conclusion that they should be at least one inch deeper, especially if the pipe be laid by contract. (Editor.)

duct's source of water supply, the routes of the new and old aqueducts, including a profile of the thirty miles of rock excavation forming the new aqueduct, and a cross section of the proposed mammoth Quaker Bridge Dam, necessary to afford the desired extra storage.

The general civil engineering features of the new aqueduct were explained and then views given of the interior of portions of the rock tunnel, (of which the aqueduct mainly consists,) illustrating the character of the ground excavated and the methods of drilling, blasting and timbering employed.

Views of the several varieties of rock drills and air compressors used in the work were also given and their respective characteristics and advantages discussed.

Tables and diagrams of tunnelling performed on the new aqueduct were exhibited and comparisons drawn from them with respect to the record of the great Alberg Tunnel, showing to what extent and why the greatest speed of tunneling on the new aqueduct was less than that attained at this famous Swiss tunnel.

The lecture was listened to with much interest and with the views presented was one of the most pleasant features of the convention.

THURSDAY, June 13th.

MORNING SESSION.

The convention was called to order by the President at 9.15 A. M.

COMMITTEE ON PIPE JOINTS AND SPECIAL CASTINGS

The President appointed the following named gentlemen as the committee to consider and report on the matter of the joints of pipes and their relation to special castings, and on the matter of special castings: Desmond FitzGerald, Charles H. Swan and Albert F. Noyes.

THE BEST METHOD OF LOCATING GATES AND SPECIALS.

The President announced the next topic for consideration, as, "What is the Best Method of Locating Gates and Specials."

Mr. Chase. I suppose that refers to locating with reference to finding them again?

The President. I suppose so; the question is a very broad one in its scope.

Mr. Chase. In order to set the discussion going I will say that it depends somewhat on the country. I am located where we only have to put the pipes a foot and a half below the surface of the ground and there is no snow, it don't make much difference where you put the gates and specials, so far as finding them again is concerned.

Mr. Tidd. As you say, Mr President, the scope of the question is pretty broad. Whether we speak of locating them on the line or locating them on the ground so you could find them again, is something which would change the whole phase of the debate. So far as locating specials is concerned, of course they have to go wherever necessity brings them on the line. In locating gates I have always taken pains to place them at the crossings of the streets, and in that matter I have been very particular to place them on the line at

such places, even if I had to cut the pipe. Then it is very easy to find them by measuring along the line. In the earlier days of water works we did not use so many gates as we do now. They were looked upon as luxuries too expensive to be indulged in to any great extent, but necessity has forced us to use them, and I am putting in more and more gates all the time. It is true that many of them, perhaps two-thirds of them, are very rarely if ever used, but no one can tell how soon he will want them or what ones he will want, and when we do want one it is sometimes worth the cost of all of them. When we came to put in so many it became necessary to locate them with the utmost care which I have always done, and I place them, as I said before, on the line of the street. I make careful measurements from two or three points, because some one of them may get lost in the course of time. Those measurements are carefully recorded in a book kept for the purpose, which the superintendent can carry around in his pocket. They are laid in short sections and very regularly, and the book has an index by means of which you can find any gate in a moment. I have found it very useful, especially in the winter when the ground is covered with ice and snow.

Mr. Tilden. In Hyde Park we have had to trust to luck a little bit, and in the matter of locating gates, particularly the sidewalk boxes, we have used a small bolt with a round head and we drive these bolts into the fences or other convenient places, sometimes into the buildings. Then, for instance, if the box is here, we go off here on a ten, fifteen or twenty-foot radius on this side and the same on the other, and in that way we have a visible mark in addition to such a location-book as Mr. Tidd has spoken of. We like it first rate. We make the radius a multiple of five every time, so we know pretty near where the box is, but not exactly. If we try a ten foot radius and don't fetch it we take a fifteen, not remembering in every instance just what the radius is, although we can tell very nearly, of course. I find that in case of snow or ice this a very good way.

The President. (Vice-President FitzGerald in the chair.) With the permission of the convention I would like to say a few words in relation to this matter. I have found the most satisfactory way of locating gates to be similar to that suggested by our friend Mr. Tidd. I think a common fault in building water works is not putting in gates enough. I find in my experience, in Pawtucket, that originally they didn't put in gates enough, and we have great trouble in shutting off certain portions of the city on the original twenty-six miles that were laid. I have endeavored since to place gates pretty uniformly at the four corners of the streets. For instance we cross a street, and we have four gates, so we can cut off simply from street to street. I would not recommend that, perhaps, universally, but I would in thickly settled districts, for I believe that the advantage of having a gate at a certain time and place is often worth much more money than the cost of the gate. And I believe, as a general rule, not enough gates are put into new works to meet the future demand. They may do well enough when the works are new and young, but when the works begin to grow, as they always do, the experience of all of you is that they grow faster than your highest expectations for them. I believe you will find that the benefit derived from a liberal supply of gates will more than counterbalance the cost. We locate our gates, as Mr. Tidd does his, on the

street line, and we can find them very easily ; as he said, we cut a pipe if it is necessary, in order to locate it exactly. Then we take the distance from the street line in a direct range and the radius distance from a given point, and that is recorded in a book which the foreman of the pipe department carries with him, so that in the winter time, or at any time when the gate is covered up, he can locate it with his tape line almost immediately. I think this is an important subject and one that will bear considerable discussion. My firm conviction is that we will find it to our advantage, in the future of the works, if we locate gates at frequent intervals.

Mr. Stacey. Some one has made the remark that different localities require different treatment, and that is true. On our works the gates were originally located carefully upon the street line, but we have found that in a large number of instances, electing, as we do, a highway surveyor every year who gets a new man to lay out a street or to relocate it, as has been done quite extensively during the past two or three years, the gates have been left in the gutter after the street is relocated, or else back of the line. So in our town, at least, it requires something beside the fence line by which to fix the location of a gate, especially when it is covered with snow and things have changed in their appearance. So I had the gates tied in by measurements and boundaries, but I found that didn't work always, because sometimes the grade of a street would be changed without our knowledge, perhaps, and nobody would know what the measurement was to find that point. I should have had to go down to the Register's office in Cambridge, I guess, and hunt up the records before I could find out where the old line used to be. So I have made a practice of taking three or four measurements, and I have gone to the foundation of somebody's house, if I could get a tape line long enough, and have found that about as sure an anchor as I could get hold of, because if a man moved his house I generally knew it. And, certainly, when I had three or four measusements, they wouldn't *all* be moved before I could hear of it and pick up the location again. I should think in a new town where an established rule is followed in laying out the streets, or in a city like Pawtucket or Providence, or in other places where the lines of the street are not changed, it would be safe to locate from the line of the street, but in such a town as mine the foundation of a man's house is a more certain thing to tie to, as that is likely to last a good deal longer than the fences, or the street line, or the grade of the street.

A paper by Mr. S. E. Babcock, Civil Engineer, of Little Falls, N. Y., "on the Aeration of water supplies by natural canals and low dams," was listened to. After discussion by Messrs. FitzGerald and Billings, Mr. Babcock exhibited a series of photographic views of the water works at Little Falls.

The convention next listened to a paper by W. C. Boyce, Civil Engineer, of Worcester, Mass., on the subject, "Can tests by tubular wells be relied on to show the *amount* of water that may be obtained for a public water supply?"

MORE MEMBERS ELECTED.

The President. We will now take up some additional applications for membership, which the Secretary will please read.

The Secretary. I have received the following applications for membership,

all of which have been examined by the Executive Committee and approved :

RESIDENT ACTIVE—H. W. Conant, Superintendent, Gardner, Mass.

J. A. Gould, Assistant Engineer, City Engineer's Office, Boston.

ASSOCIATE MEMBERSHIP—A. W. Morgan Manufacturing Co., Buffalo, N. Y.

The Secretary was instructed to cast the ballot of the convention for the gentlemen whose names he had read, which he did and they were declared elected.

Charles H. Swan, Civil Engineer, of Boston, read a paper on "Covered Reservoirs." The paper was discussed by Messrs. Allis, FitzGerald, Hawes, Babcock, Tidd and Prof. Drown.

ELECTION OF OFFICERS.

The Committee on Nominations reported the following list :

President—Hiram Nevons, Cambridge, Mass.

Vice-Presidents—Dexter Brackett, Boston, Mass.; W. B. Sherman, Providence, R. I.; V. C. Hastings, Concord, N. H.; S. S. Coolidge, Bellows Falls, Vt.; Geo. P. Wescott, Portland, Me.; Chas. E. Chandler, Norwich, Conn.

Secretary—R. C. P. Coggeshall, New Bedford, Mass.

Treasurer—Albert S. Glover, West Newton, Mass.

Senior Editor—Prof. Geo. F. Swain, Boston, Mass.

Junior Editor—Walter H. Richards, New London, Conn.

Executive Committee—Frank E. Hall, Quincy, Mass.; William R. Billings, Taunton, Mass.; Edwin Darling, Pawtucket, R I.

Finance Committee—Geo. E. Batchelder, James H. Hathaway.

The report of the Committee was accepted.

Mr. Nevons. Allow me to say a word before the motion is put, for I think it will facilitate matters if I say what I have got to say now and have done with it. I am very much surprised that the committee should have presented my name, especially after the conversation I have had with them. I do not consider myself competent to hold the office of President of this Association, and for that reason, if for no other, I feel it my duty to decline the honor which the committee has so kindly suggested be conferred upon me. Moreover Mr. President, you know you are coming down to Cambridge in the fall, and we are going to make you have a good time if we possibly can, and I know I can be of more service to you then, as a sort of fielder to assist the president whom you may elect, than I could be if I myself were president. I shall have to decline.

Mr. Walker. As chairman of the committee I would say that Mr. Nevons was our unanimous choice, as he was the choice of every member of the Association who spoke to us in regard to whom we should select. We have reported his name because there was such a pressure brought to bear on us that we could not have helped it if we had wished. (Applause.)

Mr. Billings. I hope Mr. Nevons will allow the Association to decide for itself who should be its president. It certainly is a better judge than any one man can be.

Mr. Nevons. Another thing, I ought to say, Mr. President, and that is I shall be obliged to go away this afternoon, and the president who is elected

to-day ought, in accordance with our custom, to remain with you and enter upon his duties before you adjourn. I regret it very much, but my engagements will compel me to return home this afternoon.

The President. I will relieve you of any embarrassment on that account, Mr. Nevons, for I will attend to your duties today and tomorrow, if you desire. (Applause and laughter.)

Mr. Nevons. And for the rest of the year? (Laughter.)

The President. No, sir, not for the rest of the year, but I certainly will assist you in every way I can, and I haven't any doubt but what every member of the Association will do the same. (Loud applause.)

On motion of Mr. Hawes the secretary cast the ballot of the convention for the nominees, and the President declared them elected officers for the ensuing year.

Adjourned to 7.30 P. M.

EVENING SESSION.

The President, having called the convention to order, announced that he had been requested by Mr. Sellew, one of the Board of Public Works, to say that the Board would be pleased to meet any of the members at the City Hall in the morning; also that City Engineer Gray would make arrangements for as many as desired to visit the new reservoir.

Mr. Hall. I move you, Mr. President, that the thanks of the Association be tendered to His Honor the Mayor, and to the city officers for the kindness they have shown us during our visit here. [Applause.]

Adopted.

An interesting paper on "The use of relief or safety valves in distributing systems" was then read by S. E. Babcock, Civil Engineer.

DISTRIBUTION OF SKETCHES.

Mr. Sherman. I have to report the number of contributors of sketches as twenty-two. There are three subjects having two sheets each, which would make twenty-five single sheets. I will read the subjects, and my colleague on the committee will bring the sketches forward for distribution.

1. General Plan Hingham Water Works, C. W. S. Seymour.
2. Gate House and Chamber, Newton, A. S. Glover.
3. Waban Hill Reservoir, Newton, H. N. Hyde, Jr.
4. Gate House, Marlboro, George H. Stacy.
5. Gate Chamber Wellesley Water Works, (two sheets,) F. S. Fuller.
6. Pump House and Connections, Taunton, (two sheets), W. R. Billings.
7. Gate House, New London, W. H. Richards.
8. Gate House Details, West Newton, A. F. Noyes.
9. Gate House Wentz Farm Reservoir, Philadelphia Water Works, Wm. B. Sherman.

10. No. 3 Pumping Station and Pipe System, Pawtucket Water Works, (two sheets,) Edwin Darling.

11. General Plan Norwich Water Works, C. E. Chandler.

12. Gate House and Reservoir, Fitchburg, T. C. Lovell.

13. Aerating Canal, S. E. Babcock.

14. Quincy Water Works, Pump House and connections, F. E. Hall.

15. Quincy Water Works Guide Screens, L. A. Taylor.

16. Westboro Water Works Gate House, Phineas Ball.

17. New Haven Water Works General Plan, S. E. Granniss.

18. Middleboro, Mass., General Plan, G. E. Beals.

19. New Bedford Water Works Gate House, R. C. P. Coggeshall.

20. Nantucket Water Works Intake, W. F. Codd.

21. New Bedford Water Works, apparatus for flushing hydrants, A. B. Drake.

22. Boston Water Works Gate House, Parker Hill Reservoir, W. F. Learned.

The numbers of these different sketches vary. Some members have presented 21, I think that was lowest, some have presented 30, 40 or 50, some as many as 100 sheets. It was therefore impossible to make full sets for all the members. It happily turned out that we were able to make a full set for those members contributing, and we decided to make the distribution in this manner: that we would present full sets to those who had contributed, and would place the remainder on the tables in the room at the rear of the hall, allowing the members to select for themselves as long as they lasted. I would also say that the secretary has quite a number of sketches which have accumulated in his hands in years past; and unquestionably there are persons here who have not been present at one or two meetings previous to this, who would be glad of an opportunity to secure some of the old copies. If they will avail themselves of this opportunity we will be obliged to them.

PLACE FOR HOLDING THE NEXT CONVENTION.

The President. Before we proceed further I will bring up a subject which is of interest to all of us, and that is: Where shall we meet next year? The Chair waits any suggestion.

Mr. Hawes. I invite the Association to meet in Fall River next year. We never have had good accommodations there, but a new hotel is now building to be opened in August, and I guess it will last for a year. [Laughter.] I should be pleased to meet the gentlemen there, and will do what I can to make the meeting a pleasant one.

Mr. Stacey. I move, Mr. President, that we accept the invitation.

Adopted.

An interesting paper by L. Fred Rice, Civil Engineer, of Boston, on "Testing water meters and some things learned thereby," was next presented.

EXHIBIT OF WATER WORKS SUPPLIES.

Mr. Jenks, for the committee having charge of the Exhibit of Water Works Supplies, made the following report which was received and placed on file :

EXHIBITS AT THE SEVENTH ANNUAL CONVENTION

OF

THE NEW ENGLAND WATER WORKS ASSOCIATION,

HELD AT PROVIDENCE, R. I., JUNE 13, 14 AND 15, 1888.

Hersey Meter Co., Boston, Mass., water meters.

Chapman Valve Manufacturing Co , Boston, Mass., hydrants, gates and valves.

Walworth Manufacturing Co., Boston, Mass., water faucets, plumbers' tools and the Hall tapping machine.

Ludlow Valve Manufacturing Co., Troy, N. Y., non-freezing hydrants, and valves for water, gas and oil; air and tank valves.

A. W. Harris Oil Co., Providence, R. I., samples of valve and engine oils; scouree for polishing metals, and lubricating compound.

Ross Valve Co., Troy, N. Y., fluid pressure regulator and apparatus for regulating steam car heating.

Vacuum Oil Co., Boston, Mass., samples of oils.

Geo. E. Winslow, Waltham, Mass., reservoir indicator and recorder.

Jarvis B. Edson, New York city, recording pressure gauge.

R. D. Wood & Co., Philadelphia, Pa., cast iron water and gas pipes, lamp posts, valves and hydrants.

Tuerk Hydraulic Power Co., New York city, water motor.

A. W. Morgan Manufacturing Co., Buffalo, N. Y., extension shut-off boxes for service cocks, and valves in street mains.

Fred. Adee & Co., New York city, plumbers' supplies.

Builders' Iron Foundry, Providence, R. I., crosses, T's, elbows, valve boxes and reducers for water pipes.

Henry F. Jenks, Pawtucket, R. I., new designs of drinking fountains.

Union Water Meter Co., Worcester, Mass., rotary and piston meters, and machine for testing tensile strength, and a device for tapping water pipes under pressure.

Whittier Machine Co., Boston, Mass., hydrants and gates.

Samuel A. Strang, 30 Pine street, New York, the Deacon waste water meter.

The Oliphant & Hageman Filter Co., New York city, cold water filter and feed water heater and purifier; waste and water meters.

The Water Waste Prevention Co., New York city, Thompson water meters

S. R. Bullock & Co., New York, illustration of stand pipe.

Chas. Carr, Boston, Mass., illustration of hydrant.

E. R. Jones, Boston, Mass., illustration of tapping machine.

CLOSING EXERCISES.

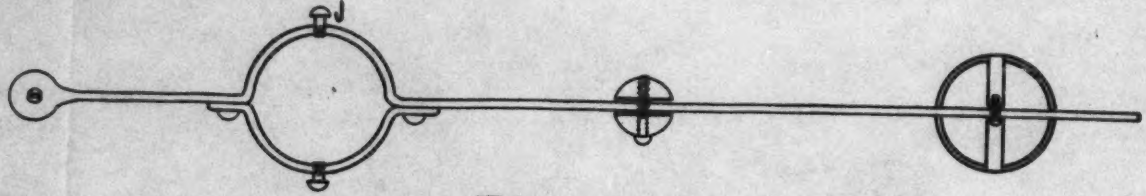
Mr. Billings. It is customary at the close of our meetings to make some expression of our appreciation of the efforts of those who have helped to make our gathering pleasant and profitable. There is one officer, who, I think, is especially entitled to our remembrance to-day. When he was chosen last year we know he accepted the office unwillingly, but he took it as his duty, because he is always ready to do what he considers best for the Association; and, as he always does when he undertakes anything, he has done his duty in the office he has held during the past year with his whole heart, with great success and with good results. Those of us who have been connected with him in the management of the Association are glad to bear testimony before those of you who have not been so intimately connected with him to the cordial manner in which our president has co-operated with us during the year. I take great pleasure in moving a vote of thanks to President Darling for his services, and I ask the secretary to put the motion. (Adopted).

The President. Gentlemen of the New England Water Works Association, if I have contributed in any degree to your pleasure during the year I have fully accomplished what I hoped I might do. I assure you I appreciate the spirit of the expression of regard which you have just made, and I thank you all personally and cordially for the kindness you have shown me during my administration as president of this Association. (Applause.)

Mr. Sherman. During the session of the convention we have listened to some very able papers, and I move you, sir, that a vote of thanks be tendered to those members who have taken pains, at considerable labor, as the papers have shown, to prepare these papers and to present them to us. Adopted.

Mr. Darling, speaking in behalf of Mr. Nevons, the new president, made for him a few humorous remarks accepting the honor which had been conferred on him, and then declared the convention dissolved.

The concluding feature of the convention was an excursion down Providence river on Friday morning at eleven o'clock. At the time named a party of about sixty members and guests assembled upon the steamboat. The sail was extended down the river as far as Rocky Point, and on the return trip a landing was made at Crescent Park, where the party partook of a shore dinner. After cigars had been lighted brief remarks were made by ex-Gov. Davis, of Pawtucket, and Messrs. Darling of Pawtucket, Noyes of West Newton, Rice of Boston, Billings of Taunton, and Hawes of Fall River. In order that the different members might take the out-going afternoon trains from Providence, an early start for that city was made, the wharf being reached at about three o'clock P. M.



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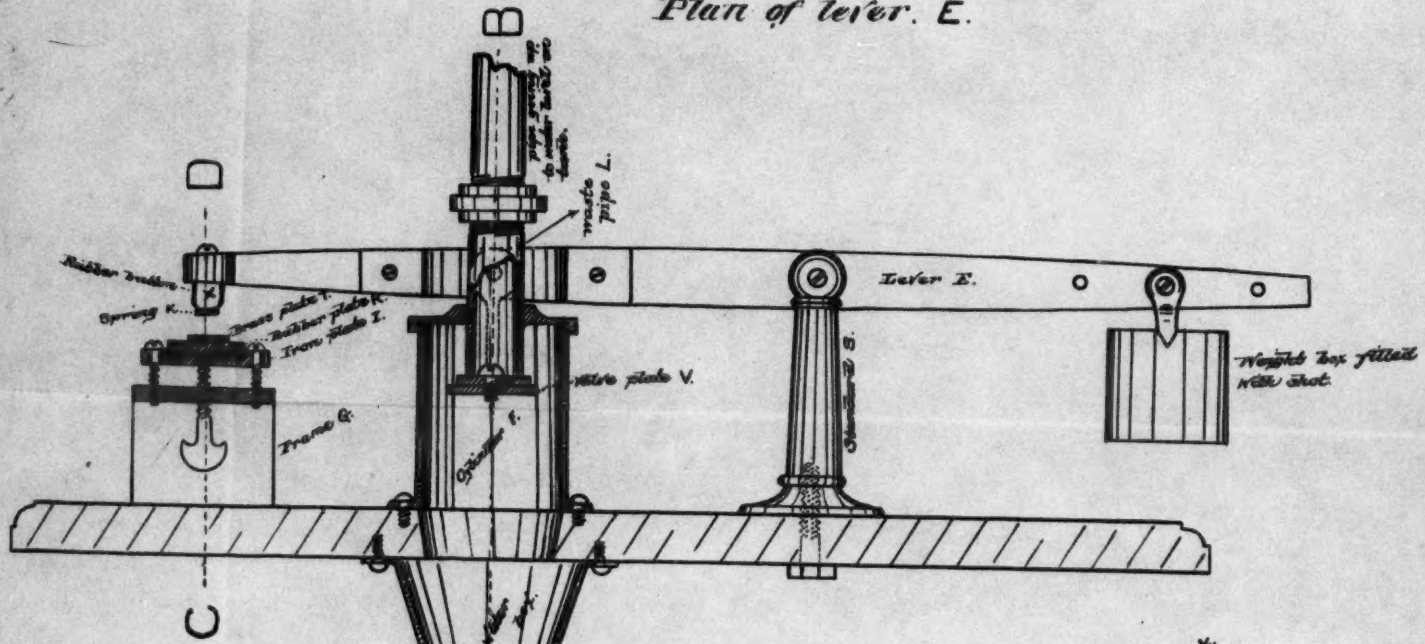

Side Elevation.

Apparatus for notifying when High Water Level is reached in Reservoirs or Water Tanks.

W. P. Whittemore Supt.
North Attleboro
Mass.

End Section through CD

End Section through AB

Vane plate V.

HIGH WATER ALARM FOR RESERVOIRS AND TANKS.

BY

W. P. WHITTEMORE, Supt. Water Works, North Attleboro, Mass.

The subject of this paper is a very simple and inexpensive apparatus, designed and built a little over two years ago, and now in use, as it has been ever since it was made, at the North Attleboro water works, indicating with exactness, at the pumping station the moment when high water is reached in the tank. The apparatus is of use whatever may be the relative location of the tank or reservoir and pumping station, and the alarm bells may be increased in number and so located as to indicate at the office, the residence of the superintendent, the pumping station, or at any convenient point, the moment when high water mark is reached.

In the construction of the apparatus one need not confine himself to any particular dimensions if the general proportions of the sketch are observed. Referring to the drawing we have a base of plank or iron, a standard with a fork at the top, carrying a lever made in two pieces, a weight box, a waste water cylinder and waste water tunnel to conduct the waste water to a suitable drain pipe, an iron frame, "G," iron or brass plate, "I," about 6 inches long by 1¼ wide, ¼ thick, a Vulcanite rubber plate, "R," brass plate, "F," a flat spring, "K," of sheet brass, ½ wide, 3¾ long, 1-32 thick, bent as shown, a rubber button, "X," fastened to the lever, "E," one valve plate, "V," with leather seat, fastened by a small screw, two valve hangers, that are screwed into the valve plate and connected to the lever, "E," by screws at "OC." The lever, "E," is made in two parts, as shown, so as to straddle, in this case, a ½ inch brass pipe that is connected by a union joint to the overflow pipe that runs up through the tank bottom to the proper high water level. This ½ inch brass pipe is securely fastened to the cover of the cylinder, "F," and projects down through this cover into the interior of the cylinder about 1⅜ inches. This cover is also firmly screwed to the cylinder "F." The valve hangers, also, go down through this cover, through holes drilled large enough for them to move easily up and down. The weight is a brass box, or round bucket, about 2½ in. deep and 2 inches diameter, or thereabouts, the bail of which is fastened by one screw to the lever, "E," so as to prevent its slipping from place. This box, or bucket, is to be filled with shot, more or less, as may be desired. The rubber button is fastened to the lever "E," by a small screw that goes through the lever, and into the button, but not through it. The purpose of the button is to insulate the lever from the spring, when the connection is made between the spring, "K," and the plate, "T." The frame, "G," is made of iron or brass, bent as you see by the end section through "CD," and is for the purpose of sustaining the iron plate, "I." Upon this plate, "I," is the strip of Vulcanite rubber, about 6 inches long, 1 inch wide, 3-16 inches thick, and on top of this rubber plate is placed a brass plate about 3 inches long, ⅝ wide and 1-16 thick. These plates and the rubber plate are

held in place at one end by the binding post, "P." At the other end is another binding post similar to this, that holds the flat brass spring, "K," in place. This spring, "K," is located directly over the brass plate, "T."—(These so-called "binding posts" also hold one end of the wire from the station, and will be mentioned hereafter). There are two elevating thumb-screws, that go up through the standard, or from "G," under the plate, "I," and four holding-down screws, that go down through the plate, "I," and screw into the frame, "G." Their office is to adjust and hold in place the plate, "I," as you will see that lowering or raising the plate alters the amount of movement of the lever, "E," consequently increasing or diminishing the amount of valve opening, and thereby effecting the quickness of the escape of water from the overflow pipe. The use of the cylinders, "F," and waste water tunnel is principally to prevent the water from flying when discharging, and becoming a nuisance. The cylinder cover becomes, in addition, a support to the end of the waste pipe and a guide to the valve hangers. Now, from one or the other of these before-mentioned binding posts, "P," is a wire running to the station, and there connecting with a three or four-cell Leclanche battery, located, in this instance, in a handsomely finnished black walnut box, fastened to the wall of the station, and also connected with this battery is a four-inch electric bell. There is provided, just under this bell, connected with the wires, a switch, so that, if desired, the long continued ringing of the bell may be stopped. The other wire from this battery may be "grounded" by connecting it with some convenient gas or water pipe. From the other binding post, "P," is a wire "grounded" in like manner as the one at the station. Now the action of this instrument is simply this:—After having fastened the base to some suitable fixture, either to the brick work under the tank, or to any suitable firm foundation, connect the pipe, "L," by means of a union joint to the overflow pipe that goes up to the proper level of the water. Then connect the waste tunnel by means of a union joint to a suitable drain pipe. Now connect the wire from the station to one binding post by means of the holding-down screw in the top of it, and then connect the ground wire with the other post in like manner. See that all these connections are clear and bright and firmly made. Now adjust the plate "T" by means of the adjusting thumb screws, so as to give whatever valve opening you may think suitable; in this case it is about 1-16 of an inch. See that the rubber button rests upon the spring "K," and that when pressed down to the plate "T" it has a good fair bearing; now put shot enough into the weight box to hold the lever and valve plate up against the end of the waste pipe "L," so that it would require a column of water about 27 or more inches high in the overflow pipe to force open the valve plate, thereby pulling down the lever and bringing the spring and plate together, closing the circuit, which will cause the alarm to ring as long as there remains any amount of water over and above the 27 inches, or whatever amount it is weighted at. The two binding posts "P" and binding screws, spring "K," and plate "T" I should have gold-plated, for the reason that the location of this instrument must necesssarily be very damp and would corrode quickly and the cost would be slight; the other parts could be well painted. Now that you have the instrument properly set up and connected at both ends, the station and tank, you commence pumping.

When the proper water level is reached or just a bit more, over goes the surplus water into the overflow pipe; the valve plate is pushed down, at the same time causing the lever to bring the spring and plate together, closing the circuit and your alarm bell rings and will continue to do so, until, as I said before, it is either switched off or the water stops running; then the weight closes up the valve and breaks the connection, and all is ready for the next day's duty. In constructing this instrument there need be no extra nice fits, nor need it be made large and cumbersome. The cost of the one at the North Attleboro station, including everything but the wire, poles, etc., from the station to the tank, a distance of about 2,500 or 3,000 feet was about $30.00. It has worked successfully thus far, and I see no reason why it should not continue to do so. Of course, like everything else it must have proper care, but that is very little. It has now been in use over two years.

DISCUSSION.

The President. The paper is now open for discussion.

Mr. Rice. Do I understand that the apparatus is located at the pumping station?

Mr. Whittemore. The apparatus is located directly under the tank and the battery is located in the pumping station.

Mr. Rice. Your water is in a tank?

Mr. Whittemore. In an iron tank 60 by 40, about 2,500 or 3,000 feet away.

Mr. Rice. And this is simply a device for closing the circuit or breaking it as the case may be?

Mr. Whittemore. Yes, sir.

Mr. Rice. If that should be located at the surface of the water, so that by the rising of a float actuated by the water surface, for instance, the circuit could be closed, you could still have your indicator at a distance and could save your pipe connection, couldn't you?

Mr. FitzGerald. I don't understand why it would not be cheaper to have the apparatus on the surface if your tank is protected from freezing.

Mr. Whittemore. I think a float in an iron tank, at least in our vicinity, would be bothered some by the ice.

Mr. FitzGerald. If it is covered over?

Mr. Whittemore. Ours is covered over but still it freezes. The ice forms, and when the water goes down it breaks, and then the water comes up and freezes again.

Mr. FitzGerald. I know that is so with tanks that are open, but I didn't suppose it was so with tanks that are roofed.

Mr. Whittemore. You must have your tank well ventilated if it is roofed, and you will get a low temperature just about the same. It is, of course, well to have it excluded from the light. I find ice skims over ours, but as the water is in motion, going down and then coming up when the pumps are working, the ice is broken. Still it would bother a float, and I think such an arrange-

ment would be more liable to get out of order than an arrangement like this under the tank.

Mr. FitzGerald. It seems to me it must be necessary to protect the pipe from frost.

Mr. Whittemore. This pipe goes up through the bottom, alongside the stand-pipe in the tank.

Mr. FitzGerald. The normal condition of the valve will resist a certain pressure inside the pipe, and there is some pressure on it all the time. How much water does it take to operate the valve?

Mr. Whittemore. You can have it so a gill will weight it if you desire.

Mr. FitzGerald. There is a certain quantity of water in the pipe all the time, and isn't that liable to freeze?

Mr. Whittemore. No, this need not be tight; it can drain itself. In the chamber underneath the tank I have never found anything to freeze. It is apt to be sweaty and damp, but it will not freeze.

Mr. Tidd. What is to prevent the top of the pipe from freezing in the tank and being pulled out?

Mr. Whittemore. The ice never freezes thick enough to do that.

Mr. Tidd. I have had it pull a 12-inch pipe out twice in a tank.

Mr. Whittemore. I have never had any trouble of that kind in my experience. I don't know how it would work in other places.

Mr. Fuller. I would like to inquire if this overflow might not be sealed up with the small pieces of ice so as to prevent its operation?

Mr. Whittemore. It never has been; I don't know what might happen. All I can tell you is what has been the experience of the two years I have used the apparatus. Our tank is closed on top but not tight; the covering is simply of spruce boards. Ice forms on the top, as I have said, but with our system, when the pumps are running, the water, of course, is rising, and when the pumps are stopped the water is lowering all the time; and in the extremely cold weather the consumption is so large, especially at night, that ice does not bother us.

Mr. FitzGerald. Is there only one layer of boards over the top?

Mr. Whittemore. That is all.

Mr. FitzGerald. Does that keep the light out?

Mr. Whittemore. It keeps the light pretty nearly out, but not so much of it as ought to be kept out.

Mr. Tidd. In the case I spoke of where the pipe was forced out by the ice, the pipe was a force pipe that passed up above the tank.

Mr. Whittemore. Ours is a 14-inch pipe and I never had any trouble of the kind you speak of. In fact, I never have had any trouble on account of ice. The lowest temperature of the water last winter was 49°. Last August the temperature of the water in the force main was 49°, and this morning the temperature was 52°. That is about all the variation I have noticed by a thermometer inserted in the force main close to the pump, with the bulb running

down four or five inches. I keep a record of the temperature of the water every day when we are running.

The President. Your water is taken from the ground?

Mr. Whittemore. Yes.

The President. And practically you are pumping spring water?

Mr. Whittemore. Yes.

Mr. FitzGerald. The temperature you have given us is the temperature of spring water.

The President. That is a point I wanted to understand. The slight variation in temperature is due to its being spring water.

Mr. Whittemore. The water stands on an average at 28 feet and 9 inches. This morning it was 28 feet 9 inches. I have pumped 347,000 gallons in six hours, leaving 18 feet and 9 inches in the well at six o'clock; the next morning at 7.20 I found 27 feet and 3 inches.

Mr. Tidd. The fact that you are pumping subterranean water has much to do in explaining the fact that you are not troubled with ice, because of the warmed water coming in and going to the top. I have known underground water not to freeze at all in cases where the temperature has been below zero for several days. I am satisfied, however, your apparatus never could be used where surface water is pumped. I have known surface water to freeze in tanks in bunches of ice four feet thick.

Mr. Tilden. Have you ever known of the lever failing to make the contact on account of particles of dirt on the plate?

Mr. Whittemore. Not in my experience.

Mr. Tilden. In two years?

Mr. Whittemore. Yes.

Mr. Tilden. I suppose a sliding contact would obviate the possibility of any difficulty of that sort.

Mr. Whittemore. It might, but I have never had any trouble of the kind. I have the plate gold-plated on account of dampness.

Mr. Tilden. How many times during the week is contact made, that is, in the course of your pumping; twice or three times a week?

Mr. Whittemore. Yes, or every day, if we pump every day.

Mr. Tilden. You do not pump every day, do you?

Mr. Whittemore. We pump four days in a week now, but soon we shall pump every day.

Mr. FitzGerald. I would like to ask if this same result could not be reached by having a little opening in the top of the tank, and then have the water run out on to a level, into a vessel with a hole in it so the water would not stay there, just sufficient to tilt the lever and make the connection?

Mr. Whittemore. Certainly. You can accomplish the result by any means which will move the lever and make the connection.

CAN TESTS BY TUBULAR WELLS BE RELIED UPON TO SHOW THE AMOUNT OF WATER THAT MAY BE OBTAINED FOR A PUBLIC WATER SUPPLY?

By W. C. Boyce, C. E., Worcester, Mass.

In presenting this paper for your consideration it is not my purpose to give a direct answer to the question as to whether tests by tubular wells may be relied on to show the amount of water that may be obtained for a public supply; but merely to present some facts that I have gathered from my own experience and observation as an engineer of water works, leaving the question conveyed in my subject to be answered in your own minds.

For the sake of comparison I will enumerate the chief sources of water supply. They are as follows:

First—That of lakes, artificial ponds, rivers, or the surface waters.

Second—That of dug wells or filter galleries.

Third—That of tubular wells.

The last two presumably from water of the ground. I say presumably, for it is an open question to what extent a well adjacent to surface waters may draw its supply therefrom.

The amount of water that may be obtained from surface supplies in certain sections of the country, with given water-sheds, may be quite accurately predicated; for experience has taught us that a definite proportion of the rain-fall on a water-shed of a given area may be relied upon; but with regard to the amount of water that may be obtained from the ground, it seems to me such is not the case, much depending upon the geological formation of the section and porousity of the ground through which the water flows.

True, the thickness of each deposit of loam, sand, gravel, clay, etc., may be ascertained by tests at certain places, but in this broken, New England country, is it safe to assume the stratification to be the same one hundred feet distant from where the test is made?

Of this we may judge somewhat by the topography of the section. And in connection with tests to ascertain the stratification, (the kind and condition of material, and quantity of water therein contained), there should be made a careful study of the topography of the water-shed in which the tests are made.

Still some freak of nature might bar us from obtaining all the ground water that we might reasonably expect within the water-shed under consideration, or might allow us to draw from a neighboring water-shed; but without proof positive to that effect, it would seem reckless to assume that we can.

Assume that the result of tests by tubular wells as they are usually made, at a given place, are favorable, that is, a number of wells are driven, and each

well, or most of them, yield a good quantity of water. Some are pumped clear of sediment and others are not.

The result of such a test as the above might lead us to suppose we could obtain an ample supply of water at the place assumed, by driving a reasonable number of wells, equal to the end proposed.

The result of such an examination, alone, I do not consider sufficient evidence to warrant expensive outlay in a pumping plant with the expectation of obtaining sufficient water.

I cannot bring this matter to your attention more clearly I think, than by citing the experience of the town of Kingston, Mass., in the matter.

I first became identified with the work as engineer of construction of water works for the town of Kingston, in December, 1885; previous to which time, tests by means of tubular wells had been made by Calvin Wharton & Son, of Somerville, with the following result, as I am informed by the water commissioners:

The first well was unsuccessful on account of fine material, and a boulder encountered, which broke the pipe.

The second well, located a few feet from the first, was driven nearly to bed-rock, which was, at this place, about 45 feet below the surface of the ground; but this well was pronounced a failure because of very fine material encountered, which choked the inlets of the pipe, so that the yield of water was small.

The third well was driven nearer the river, to a depth of about 33 feet, when a boulder was encountered, which broke the pipe. This well yielded about ten gallons per minute, and though it was not pumped clear of sediment, fine material offered no impediment to the free flow of water.

The fourth well, which was driven to bed-rock, was pumped clear of sediment, and yielded about ten gallons per minute. The water rose in it nearly to the surface of the ground, and several feet above the level of the water in Jones river, at its nearest point, about 50 feet away, and was called unreservedly a good well.

On the strength of these tests, Mr. Wharton, a man of large experience in driving wells, *guaranteed any amount of water that the town might need.*

The town voted to construct the works; and a water privilege on the Jones river, near the proposed source of supply, was purchased for the town to furnish power for pumping.

A contract was made with Calvin Wharton & Son, who agreed to furnish the town 300 gallons of water per minute, by means of a system of driven wells.

In the spring of 1886, the Contractors began the work of driving wells and continued driving for a number of weeks, when they came to the conclusion that a sufficient amount of water could not be obtained in this manner at this place, the principal trouble being the very fine silicate which they encountered in the water-bearing stratum which checked the free and sufficient flow of water. Some wells were obtained which yielded a fair supply of water, but those it seemed impossible to pump clear of sediment by continued pumping.

The site of the tests and also that selected for the system of wells is west

of the centre of the town, and along the east bank of the Jones river. At this place the ground, for the distance of 75 or 100 feet back from the river is comparatively level, beyond which place the ground rises in a steep bluff, to a height of about 60 feet.

The stratification where the tests were made, was as follows, as we encountered them in going down:

First—A deposit of from 4 to 6 feet of loamy material;

Second—Gravel and sand;

Third—Very fine sand;

Fourth—Hard pan;

Fifth—Very fine silicate, sand and gravel, which contained the water, we were desirous of obtaining; and

Sixth—Bed-rock at a distance of about 45 feet below the surface of the ground.

I do not wish to be understood as conveying the idea that the parties who made the tests were not justified in believing that sufficient water might be obtained here, but simply to illustrate the fact that we may be misled by the result of tests by tubular wells. They may serve as a more or less reliable index to the amount of water that may be obtained, as the topography of the water-shed is an index pointing in the same direction.

In conclusion, I would say that in view of the probable uncertainty of the results based on tests by means of tubular wells, examinations thereby should be supplemented by investigation of all available sources of information bearing on the question under consideration.

DISCUSSION.

Mr. Stearns. I would like to ask Mr. Boyce how the supply was finally obtained at Kingston.

Mr. Boyce. There was a second water-bearing strata near the surface, and the supply was finally obtained by means of a dug well twenty feet in diameter, which yielded about 50 gallons per minute, and I believe does at the present time. Any further information as to the works, whether they have proved successful or not, may, perhaps, be obtained from the superintendent, who is here. The supply has been considered rather limited, and at present they are constructing a gallery up along the river to bring more water, by which they hope to increase their supply very much; and by going far enough in that direction there is every probability that they will get all the water they desire.

Mr. FitzGerald. How deep was the well sunk?

Mr. Boyce. It was sunk to the depth of about fourteen feet below the surface of the ground. By going further they were liable to come into this very fine material which filled up and choked the pipes, and it was also thought that they would not get much more water by going deeper.

SOILS FROM WHICH WATER SUPPLIES MAY BE DRAWN BY FILTER GALLERIES OR DRIVEN WELLS.

By Phinehas Ball, C. E., Worcester, Mass.

The subject matter in the following remarks will be based, in some degree, upon information gained in an investigation now being carried on for the State Board of Health of Massachusetts. That investigation relates primarily to the disposal of sewage of the Mystic valley upon the Saugus marshes. Only such portions of the knowledge thus far obtained will be used as pertain to the subject in hand, and other sources of original inquiry than this will also be used.

Consideration will first be given to the quantity of water held by various soils in their normal condition.

It is well known that water is ever present in all soils. But of the vast quantity we have little conception, until by experiment the fact has been ascertained. The quantity normally held is not the same in each soil, but differs with the kind and structure. Sand, loam, clay, peat, mud, and all varieties of mixtures of these, in every degree and proportion, act towards water in two distinct ways. *First.*—All soils are porous, and from this property, or by it, water passes or flows through it as through a filter. *Second.*—The earth retains, or keeps in store, a certain quantity of water. The water thus retained is not and cannot be filtered out; it can only be removed by the roots of plants and by evaporation.

The power or capacity of the soil to retain moisture seems to be closely connected with the growth of vegetation. Many experiments have been made to ascertain or determine this normal quantity. The method used has been to dry a certain measured quantity of soil and find the loss of weight, this loss representing the quantity of water contained in the measured sample. From this result the next step has been to find the number of vertical inches of contained water such soil has to each foot in depth.

The statements relating to the amount of water which various soils are found to contain are taken from experiments made from time to time in inquiries relating to the disposal of sewage. Garden loam under cultivation taken from 4 inches below surface contained 2.09 inches per foot in depth of soil, or 56,700 gallons of water to the acre.

Loam from a wood lot taken 15 inches below surface contained 2.61 inches of water in one foot of soil, or 70,800 gallons to the acre. Another sample, 6 inches below surface, 2.37 inches, or 64,350 gallons to the acre of soil one foot deep. These three samples were from soils not lately wet by rain, and were each what would commonly be termed quite dry. The next sample of loam was from a cultivated field, taken from a point within about 12 inches of a thin stream of water, flowing on the surface, and about 6 inches below the surface, this contained 4.94 inches of water to one foot of soil, or 134,100

gallons to the acre. This is a soil that would generally be called quite wet, and still the saturation point of good arable loam may possibly be higher than this sample. The quantity of water contained in a good loam soil, as per last sample, and 10 feet deep, would be equal to 1,341,000 gallons per acre, or a depth of 49.4 inches, or 4 feet 1.4 inch. A square mile of such soil (640 acres) would contain 858,000,000 gallons of water.

Common meadow mud and marsh mud are quoted as lying upon the extreme limit of soils in their capacity to retain water.

A sample of meadow mud from a point where the ground would be called well drained contained 6.32 inches for each foot in depth.

Mud disintigrated by frost, 4.03 inches.

Mud air dried lying on the surface 2.46 inches.

The last sample would be called quite dry.

In a sample of wet mud taken below the water table in the soil 9.3 inches was found. Perhaps this may be considered saturated meadow mud. Such a peat or mud soil holds 252,500 gallons of water to the acre one foot in depth, and the air-dried above stated 66,800 gallons. Nine inches of water in one foot of meadow mud and peaty matter seems, at the first view, a large quantity, but in a test of seven samples the average was 9.08 inches.

Samples of marsh mud gave the following results:

Average three samples of a kind of clay and vegetable matter, 9.76 inches.

One sample, 8.64 inches.

Clay and vegetable matter, 8.47 inches.

Clay and vegetable matter from the bank of creek, 7.74 inches.

Black mud, 6.6 inches.

Turf formation, 8.18 inches.

Mud from under water and 5 inches below the bed of a standing pool, 9.59 inches, or 260,000 gallons to the acre of soil one foot in depth.

The seven samples above quoted indicate that the power of salt marsh mud to retain water is not essentially different from that of common fresh water mud and peat. Experiments on soil from a dyked out marsh brought to a fine state of cultivation showed that it had become about like air-dried and well drained soil in our fresh water meadows.

Experiments upon sand have shown:

For a coarse, gravelly sample, quite dry, 0.93 inches.

Fine building sand, sample quite dry, 0.33 inches.

Fine Gravel, 3.13 inches.

Beach sand under mud, saturated, 4. inches.

Another sample, saturated, 4.95 inches.

The second sample on casual handling would be called quite dry. This holds only 8,930 gallons of water to one foot in depth per acre, while the last named has 134,400 gallons.

The clays and the hard-pans, which are composed of every conceivable proportion of clay, sand and gravel, have not been experimented with to find their contained water.

Out of loam, and every variety of vegetable formation, in the form of mud, peat, and all combinations of these, with sand and clay, water filters out with extreme slowness as compared with sand. Yet through these soils water does percolate; and if given time enough and ample drainage vast quantities will pass through. The really impervious soils are the clays and the compact hard-pans.

Of the loams and peaty soils this is to be said, their capacity to retain water has a normal limit. Up to that normal limit no water will percolate through the soil; it can only be removed by evaporation or by the roots of plants. What that limit is my experiments have not determined. But the samples of loam, meadow and marsh soils first given, are believed to be, at least some of them, on that normal line, that is it seems safe to say that soils of this kind may contain and hold from 162,000 to 250,000 gallons per acre for each one foot depth of soil. Yet, notwithstanding this vast quantity of water stored in the soil it is not available for the water supply of only a single family, not for a village, or a city, it is there on deposit and for other purposes than those of direct use.

The stored water for our industrial and domestic use, must come, if it comes from the soil, from the loose porous sands and gravels and the open fissures in the rocks. The driven well, or the filter gallery, can only succeed where the conditions are favorable; neither can work a miracle, when it, Moses like, smites the rock, unless it finds a fissure filled with water. My experience leads me to say that very fine sand through it may hold as large quantity of water as coarse sand, yet it makes a very unpromising field to work upon or experiment with.

The coarse sands and the open gravelly strata are the only soils which can be of any avail as supplies for village, town or city use. A few words will be said about these.

This seems to be the fact. Areas composed of good fair building sand, good clean beach gravel and sand, and the loose gravels, may contain when saturated, from three to five inches of water for each foot in depth, or from 81,400 to 135,700 gallons per acre, or from 17 to 87 millions gallons per square mile. When the quantity held by a single foot of soil is multiplied by 10, 20, 30, 40 or 50 feet, some conception can be formed of the enormous amount of water held in store in the earth.

These sands and gravelly formations are found in larger or smaller areas in all parts of the country, and wherever they exist to a large extent and reach below the water table they are valuable sources of water supply or aids to other means at hand.

The surface sand formations become useful auxiliaries to water supply in three ways.

First. On the margin of natural or artificial reservoirs. The water from

the reservoir flows back into the sandy soil on their margins, and in this manner in some instances, adds a very material and appreciable quantity to the amount in store. Or the water in the reservoir will form a dam by which the rain-water falling on its shores are held back in the soil to be drawn upon as the water in the reservoirs is drawn down.

Second. These soils along the margin of reservoirs and rivers form ample opportunities for the building of filter galleries from which water supplies may be drawn to its manifest improvement.

Third. Along rivers and small streams these soils are the store house of vast quantities of the surplus waters of the winter and spring. Along our rivers the intervals are covered in times of freshets, during which times the earth becomes saturated with water, to be slowly given out after the freshet has subsided. As most of these intervals are composed of fine sand the stored water is given out with extreme slowness, and hence the reason for our rivers continuing their flow so steadily for a long time after many of the smaller tributaries have entirely dried up.

In conclusion only one single branch of this interesting and broad subject will be touched upon and that briefly.

In attempting to make a filter gallery or in using the driven well the question always occurs, how fast will water flow through the sand into the gallery or to the well.

Now this question cannot be answered definitely by a formula of universal application. All porous soils differ so largely in their make-up that a rule or estimate which is true of one will not be true as applied to another one. The fact however, that water has a rate of flow in loose earth is well known from common experience. But of the friction head or velocity little is defined. In only one instance has it been my good fortune to ascertain with any degree of precision a single element of the question. And this limited experience is given here for what it is worth.

This is of an open ditch in the Saugus marshes, about 850 feet long and not far from six feet deep. The lower portions of the trench is in good, fair, clean washed building sand. The depth of sand will average perhaps about three feet, or one-half its depth. The drain empties into tide water and near this point. The mouth is some four feet above mean low water. This position gives some two or three hours of slack water, during which time the weir can be measured accurately with a hook gauge. The discharge of water over the weir after the drain had come down to what may be termed its normal work, ranges from 158,000 to 256,000 gallons per day.

At the upper end of the drain test tubes have been sunk in the ground on lines at right angles to it. These tubes are six feet long and are set thirty-five feet apart, and extend on each side of the drain a distance of 175 feet. The elevation of the water is taken in these tubes and in the drain at the same time. The observations seem to indicate a grade of the water line in the sand flowing towards the drain of two inches in 35 feet, or 5.71 inches in 100 feet, or 25 feet in a mile.

DISCUSSION.

The President. Gentlemen, you are now at liberty to ask Mr. Ball any questions you may desire, and to enter into a discussion of the paper he has read.

Mr. Fuller. I didn't understand about the trench. You say it was about 800 feet long, and the water was below the sand?

Mr. Ball. When we commenced to dig the canal or ditch the water was at the surface; it stood within about eight inches of the surface of the marsh, and high tides overflowed it. The water has been running out of the trench now only about a month, and to-day the water stands in the ditch about five feet or five feet and a half below the surface. In the test tubes, when they were first driven, the water table lay quite near the surface, say within a foot, but as the water has drained out from above, the water table has been constantly lowering, until it stands at a fixed point. This fixed point is the one I just gave as indicating the slope of the ground water in the soil underneath. Mr. Lyon, who had charge of the work in Lynn in the fall of 1882, told me that to his certain knowledge wells had been drained by pumping water from the ground at least a mile in two directions from where the pumps were located, so that it was evident the pumps affected the underground water over an area of between two and three square miles.

Mr. Winslow. I should like to ask Mr. Ball with regard to his experience in Lynn, at what depth he was obliged to draw the water to drain wells a mile away?

Mr. Ball. My recollection is, it ran 49 to 54 feet, but I may be at fault. It was in the neighborhood of 50 feet. There were quite a number of them but they only occupied a small space.

Mr. Rice. I did not quite understand what you meant by saying that so many inches of water could be obtained from so many in inches depth of soil. Did you mean cubic inches of water?

Mr. Ball. No, sir, I mean inches in depth. If you would separate the water from the earth you would have that depth of water. I think I have made, perhaps, between 100 and 200 experiments, and I have found that every time it comes out that way. Some of the results I gave in my paper were averages of from seven to ten experiments.

Mr. Rice. In that case, then, where you spoke of obtaining two and a fraction inches, I think, to a foot in depth of soil, it was equivalent to saying that what would be termed dry soil is really one-sixth water?

Mr. Ball. One-sixth in depth.

Mr. Rice. One-sixth of the original volume of the soil would be water?

Mr. Ball. Yes, sir. I remember in the investigations that were made in 1856 and 1857 for the supply of water for Brooklyn the conclusion reached was that the sand and clay would yield from 25 to 33 per cent. of the water, and that would give from three to four inches of solid water which the soil

would contain for each foot in depth; and upon the basis of that calculation they figured up an enormous an almost inconceivable amount of water held in the sand or in the clay. They experimented upon 72 square miles, I think, at that time, (it is some years since I looked it over,) and found a regular incline, in the same manner that I found it in Lynn, upon which the water was flowing from the highlands towards the sea. And within a few years they have availed themselves of driven wells to increase their supply, driving them to this same level.

Mr. Noyes. I would like to ask Mr. Ball, if, from his researches and investigations he has reached a conclusion as to how much of this water is available. Of course in drafting it you would not be able to reduce the sand to a state of absolute dryness?

Mr. Ball. I have attempted an experiment of that kind but the result was not satisfactory when I came to look at it. It was a single experiment made in a certain way, and, although it continued over a considerable time, fifty-five days, yet I thought it needed verifying before I stated that it gave the correct result. But that result would show that in some conditions not over one-half of the water which will be contained in sand can be drafted out. The other half, or somewhere in that neighborhood, will be retained by the sand under certain conditions. What those conditions are, I have not experimented far enough to determine.

Mr. Noyes. They are so variable that they are pretty difficult to state.

Mr. Ball. They are very variable. I am satisfied of this, that the addition of a minute quantity of clay or a small quantity of quicksand, such as we find continually in the makeup of our New England hills, will have the effect to modify very materially any result which you may get at a certain point. That is to say, if you are dealing with a territory that has two, or three, or four, or half a dozen square miles in it, at certain points you may reach a certain result, and it would seem that the territory would give you a certain amount; but it will be modified very largely by the makeup of certain strata, which, though they may not be very large, will be sure to hinder the proper drainage of the country,

Mr. Tidd. I suppose you refer to the water held by capillary attraction?

Mr. Ball. Yes.

Mr. Tidd. Of course, no part of that would be available for supply,

Mr. Ball. No.

Mr. Tidd. It is held there permanently by capillary attraction.

Mr. Ball. Yes, and it can only be got out by evaporation. I am told that, contrary to general acceptation, through meadow mud and through marsh mud there is a circulation of water that is very large. I have become perfectly convinced that the amount of water that will pass through four, five or six feet of solid marsh mud under favorable conditions is almost inconceivably large. And it is so, also, with meadow mud. Where the meadows are drained the water drainage goes on, to be sure, very slowly, but when you come to take a large area it does get through somewhere.

THE AERATION OF WATER SUPPLIES

BY

NATURAL CANALS AND LOW DAMS.

By Stephen E. Babcock, Civil and Hydraulic Engineer,

Little Falls, N. Y.

Gentlemen of the New England Water Works Association:

The mountain brook, rumbling along its rocky bottom, here a little cascade, there a pond, now coursing along a run of water-worn stones and boulders, again a waterfall, and so on for perhaps miles, yet always pure, sparkling and palatable. This is the ideal water supply—and why? Aeration and subsidence is the answer. What is aeration? Webster defines it, "to supply with common air."

Water is composed of oxygen and hydrogen, and is uniformly in the proportion of 100 parts of oxygen to 12½ of hydrogen by weight. Common air is formed of oxygen and nitrogen in the proportion of 77 parts of nitrogen and 23 parts of oxygen (Silliman) by weight.

Air is a mechanical mixture. The oxygen of the air is abstracted by all substances having an affinity for it, with the same ease as if nitrogen was not present. A chemical combination of oxygen and nitrogen forms nitric acid. The proportions then are four measures of nitrogen to ten measures of oxygen, while in common air the proportions are four measures of nitrogen to one of oxygen. (Stockhardt.)

This is a striking example of how wonderfully the properties of bodies change when they chemically combine with each other. When *mechanically* mixed together the constituents of nitric acid form a life-sustaining gas, while when *chemically* combined they form one of the most corrosive fluids.

Oxygen has the greatest range of affinity of any known substance. Oxygen is absolutely necessary to all living creatures. Every combustion, however familiar to us, is a process of oxidation, in which the oxygen of the air combines with the particles of the burning material.

ORGANIC CREATION.

Oxygen, hydrogen, nitrogen and carbon are the four elements which the Creator has established as the base upon which the whole structure of organic creation rests; and from their combination with inorganic matter all the various forms of animals and vegetation proceed; yet the inorganic matter bears a very small proportion to the whole. Take an oak tree. Out of every 100 pounds only two to four pounds are inorganic or ashes, and about the same proportion holds true of the animal kingdom. Oxygen seems to be the agent by which the changes in organic nature are brought about. There is no chemical change in organic nature without heat. Heat is the outward evidence of combustion, and as combustion is a process of oxidation, it follows

that the changes of organic nature are substantially produced by oxygen as the agent. All animate nature is constantly undergoing a change. There is no stand-still. All animal and vegetable living matter of to-day will, in the course of a short time, be again resolved into the four elements, together with the different inorganic matters of which they are composed. And so the ceaseless change goes on, as it has gone on for centuries. Oxygen has been the principal active agent through all this, all tending to purity again. Were there not some such simple, yet universal and powerful agent constantly at work, the earth would have been uninhabitable centuries ago, due to the fouling of the water supply, if from no other cause. Must it not then be true that water purification is due primarily to oxidation; and if we try to imitate nature closely, will not our success be measured by the nearness with which we approach with our imitation? Is not nature's process of oxidation, by using the oxygen of the common air, the most available agent? Common air is the most abundant form of matter in and about the earth. Does not the oxygen of the air combine with the impurities, form new chemical combinations, the force of gravity precipitate them, and are they not thus removed and the foul water made wholesome? Is not this the true explanation of the purity and wholesomeness of the rock-bound mountain brook?

PROPORTION OF AIR WATER WILL ABSORB.

Regnault, the French chemist, gives the proportion of oxygen which water will absorb. He says:

"At the ordinary temperature water dissolves about 46-1000 of its volume, or in other words, one litre of water dissolves 46 cubic centimeters of oxygen, or 100 cubic inches of water will dissolve 4.6 cubic inches of oxygen."

Wanklyn, the well known English water analyst, also gives the possible proportion of air which water will take up. He says:

"Water is capable of absorbing, in a greater or less degree, every gas and every vapor which is placed in contact with it.

"All water which has been kept in open vessels is necessarily charged with oxygen and nitrogen gases, inasmuch as these gases form the chief constituents of the atmosphere; and if any sample of water be freely shaken up with large volumes of air, it will presently become charged with nitrogen and oxygen in certain well ascertained proportions, dependent on a physical law.

"A litre of water freely shaken up with large volumes of air at 15 deg. Cent. will absorb 17.95 cubic centimeters of air, the composition of which is:

Nitrogen,	65.1 volumes
Oxygen,	34.9 volumes
	100.0

"The composition of the dissolved air is governed by the relative proportions of nitrogen and oxygen gases in the atmosphere, and by the coefficient of absorption of each gas at the temperature at which the absorption takes place. At 15 deg. Cent. (according to Bunsen) the absortion coefficient of ni-

trogen is 0.0148, and that of oxygen 0.0299, while the relative volumes of oxygen and nitrogen in air are:

Nitrogen,	79 volumes
Oxygen.	21 volumes
	100

"The relative proportions of nitrogen and oxygen which water dissolves from the atmosphere at 15 deg. Cent. are therefore, according to the law, 0.0148x79, 0.0299x21, which gives in percentages nitrogen 65.1 volumes, oxygen 34.9 volumes, total 100.

"If water be taken from rivers and springs and be bottled up without being freely exposed to the air, it will often be found to exhibit a very different ratio between the dissolved nitrogen and oxygen gases.

"Thus in the autumn of 1859, W. A. Miller found that a litre of Thames water at Woolwich contained 63.05 C. C. of dissolved gases, the composition of these gases being:

Carbonic acid,	48.3 C. C.
Nitrogen,	14.5 C. C.
Oxygen,	0.25 C. C.
	63.05

showing extraordinary diminution of oxygen.

"Higher up the river the ratio of nitrogen to oxygen was quite different. Thus at Kingston, Miller found in a litre of Thames water 52.7 C. C. of gases, consisting of:

Carbonic acid,	30.3 C. C.
Nitrogen,	15.0 C. C.
Oxygen,	7.4 C. C.
	52.7

As will be observed, the ratio of the nitrogen to the oxygen in this water is very nearly that which they require in a perfectly aerated water.

"Undoubtedly the Thames water taken out of the river at Woolwich, owes its deficiency of oxygen to the reducing action of urea and other matters poured into the river in the form of sewage."

SUBTERRANEAN WATERS.

Again I find that in a paper read before this association at Manchester, in June, 1887, Mr. Chas. Brush, C. E., of Hoboken, N. J., says:

"It is absolutely essential to good water that there shall exist in it a certain equilibrium of animal and vegetable life in order to produce and regulate the quantity and quality of gases essential to maintaining it in good condition. Prominent among these gases is oxygen—not the oxygen of which the water is actually composed, but rather additional oxygen in solution in the water, which varies greatly under different conditions. With an excess of oxygen in

solution, stagnant water is never found. Filtered waters, or what is practically the same thing, waters obtained from subterranean sources of supply, such as galleries or deep closed wells, after passing through natural filter beds, are generally bright, clear and quite palatable. If allowed to stand any length of time, however, in an open reservoir, such water soon deteriorates."

The philosophy of this probably is, that the absorption of oxygen from the air again causes new chemical changes to occur, the composition of the water is changed, and for the worse probably. If left a great length of time the new combination would throw down precipitates, and the water would be essentially changed in its chemical constituents.

Again Mr. Brush says:

"The best supply is always obtained from water in motion. All waters, and especially those obtained from the surface streams, are better at some seasons of the year than at other seasons, and these seasons differ with the different sources of supply. Generally, however, the worst season with any is either in mid-winter or in mid-summer. In the former case, when the streams are frozen over, the air is no longer in contact with the water, and consequently the water lacks life. In the heat of summer, especially after luxuriant vegetation, the oxygen in solution in the water seems to be used up to a greater or less extent, and there is an excess of vegetable life. In both cases the result is a fishy taste and smell, and algæ are likely to develop."

ROYAL COMMISSION ON OXIDATION.

The English Royal Commission on water supply (1863) in their report say:

"If the waters of the Thames had no impurities beyond the solid mineral contents, the question as to their wholesomeness and general suitability for the supply of the metropolis (London) would be easily disposed of.

"But attention has been called strongly to the organic impurities contained in Thames water, which, though more indistinct in their form and less appreciable in their quantity, are said to be more deleterious in their nature and to render the water, if not dangerous and unwholesome, at least liable to suspicion. The organic compounds dissolved in the water appear to be of very unstable constitution and to be very easily decomposed, the great agent in this decomposition being oxygen and the process being considerably hastened by the motion of the water.

"Now as such waters contain naturally much air dissolved in them, the decomposing agent is ready at hand to exert its influence the moment the matter is received into the water, in addition to which the motion causes a further action by exposure to the atmosphere, and when (as in the Thames) the water falls frequently over weirs, passes through locks, etc., causing further agitation and aeration, the process must go on more speedily and more effectually. The effect of the action of oxygen on these organic matters, when complete, is to break them up, to destroy all their peculiar organic constitution, and to re-arrange their elements into permanent inorganic forms, innocuous and free from deleterious quality."

ALUM.

Alum is the substance now almost universally used in the patent filters of the present day, yet an examination into its chemical constituents would seem to show that its efficiency is due to the large proportion of oxygen that goes to make it up. Its chemical symbol is Al_2O_3, $3SO_3+KO$, SO_3+24HO, which being reduced to its elements indicate that 27.38 parts of the earthy metal aluminium, 64 parts of sulphur, 39.19 parts of potassium, 24 parts of hydrogen and 320 parts of oxygen, make up the whole.

HUMBER ON OXIDATION.

Humber, in his work on water supply, says:

"Oxidation is another process carried on by nature for the purification of fouled water. It operates upon the class of impurities which, with one exception, are most to be feared, viz., organic matters liable to decomposition or already partially decomposed. The oxygen which is always dissolved in water exposed to the air and the free atmospheric oxygen with which the organic matter is brought into contact by the motion of the water, combine with that organic matter, thereby converting it into harmless nitrates, nitrites and carbonic acid. The more violent the agitation and more complete the aeration of the water, the more thoroughly will the organic matter be broken up and changed into these innocuous inorganic forms. The purifying agent is always at hand and in superabundance; it is only necessary to utilize it by bringing it into contact with the substances upon which it has to act."

The concurrent testimony of all who have looked up the question of water impurities and their removal seems to be, that a violent mixing of common air with water is the most effectual and natural remedy.

AERATION AT LITTLE FALLS, N. Y.

At Little Falls, N. Y., where I am now engaged in constructing a water works system, the source of supply is an exceptionally pure mountain brook of three to four millions gallons daily run. It is the finest trout brook in the whole section around Little Falls, yet as I bring the water 8¼ miles through an enclosed conduit, I concluded to try and imitate nature's process of improving it, and with what success the following description will enable you to judge:

The closed conduit terminates at a point about 2,500 feet from the distribution reservoir. From here to the distribution reservoir I constructed an open, paved channel to near the distribution reservoir. The object of this open channel is to aerate the water by causing the same to pass over a series of sixteen weirs, 10 feet long, 2 feet high, distributed along the open channel at intervals of 50 and 100 feet apart, as the contour of ground admits. The paved channel begins at end of conduit, starting with a retaining wall, and is 3 feet wide on the bottom, 5 feet from top of bank down to grade, 3 feet 9 in. of which is excavation in natural soil. The excavation is utilized to form

tow path and berme banks, 6 feet wide, on each side of open channel throughout the whole length of the same, preventing any surface drainage from entering the canal. The open channel is carried 390 feet to a ravine or depression in the surface of the ground; here a retaining wall is built up to top banks and 2 feet above the natural surface of the ground; the water is then carried in a pipe 160 feet, through under the surface of the ravine. At the outlet another retaining wall is built up to top bank and 2 feet above the natural ground. Here the open channel starts again and is carried along for 580 feet to another ravine 100 feet long, where the water is again carried under through pipes and protected by vertical walls at each end, and with weirs or dams placed 50 and 100 feet apart, of the same size and dimensions as first stated. The water is again carried 700 feet in open channel to a point near the line of a by-wash canal, which carries the water of the several streams formerly running through the reservoir past, without entering the reservoir enclosure. From this point the water is conveyed in an iron pipe, 970 feet, to and through the bed of the distribution reservoir to a point out in the center of the same, distant about 430 feet from the gate-house and 100 feet from the sides of reservoir; here the pipe is turned up vertically and held in place by a rectangular mound of masonry, which is carried up 2 feet above water surface of the reservoir. The water is allowed to fall over the sides of a square coping on top of the mound, giving a final oxidation to the water as it mingles with the waters of the reservoir.

The total oxidation of the water after it has been confined in $8\frac{3}{4}$ miles of conduit is represented by the aeration over 16 weirs or dams, 10 feet wide 2 feet high, a total length of open channel 1,600 feet, with a final overfall in the centre of the reservoir, removing all possibility of fouling the water by surface wash on the edge of reservoir. Again, by passing the water through pipes under the two ravines, all the surface water and drainage from the end of the conduit, to the diverting, or by-wash canal, is carried on the surface of the ground through these ravines, and cannot contaminate the water in the open canal.

Near the point where the iron pipe from the last section of aerating canal passes under the diverting or by-wash canal, I placed a branch with a pipe leading into the by-wash canal, locating valves on two ends of the branch. The aerating canal forms also a series of subsiding ponds or reservoirs, and to provide for a ready means of cleaning them, I placed the above mentioned branch controlled with its valves. Whenever the canal ponds become filled with precipitated matters, the line leading to the distribution reservoir may be closed, the one leading to the by-wash canal opened; this allows all the water to waste into the by-wash canal. To clean the ponds and canal, it is only necessary to stir up the deposits with brooms or other suitable tools, and the water carries them along down and out through the by-wash canal to waste, until such time as the canal has been cleaned and water runs clear, when by changing the valves the pure water may again be sent into the reservoir. The water is kept in a constant state of agitation with the air, from the time it strikes the first dam to the end of the aerating canal. This I claim to be a fairly close imitation of nature's own way of rendering water pure and wholesome as well as pleasant and palatable.

MICRO-ORGANISMS.

Yet there is one item in water purification also to be looked into, the exception referred to by Humber. That it is a disputed point as yet as to how far aeration goes in removing the living germs, seems to be the fact. Humber says :—

"The class of impurities of which exception was made as being that most to be feared, is unfortunately the class upon which the action of simple oxygen is of the most doubtful efficiency. The microscopic organisms known as germs would seem to defy the action of oxygen by that very element of vitality which renders them so persistently dangerous. While, however, the opinions of scientific men on this point are still so conflicting, it would be unwise here to do more than recommend the strictest caution."

COKE FILTER.

I determined to obviate this possible danger by adding a coke filter in the inlet chamber of the distribution reservoir. The particular description of inlet chamber and filter is as follows :—

The inlet chamber is of rubble masonry divided into three compartments. The first compartment nearest the water is arranged with two sets of screens running from top to bottom of the house; 3 inlet tubes are placed on the inner side of the chamber, governed by regulating valves; these inlet tubes are placed at different elevations below the surface. Water may be drawn from either one as may be required. The water then passes into the middle chamber, which is a coke filter bed. The coke extends down from the top to a rack placed 5 feet above the bottom of the chamber. From this chamber the water is drawn into the third chamber by another inlet tube placed 2 feet above the bottom and below the coke. From the third chamber two pipes lead the water down to the distribution system. A 12-inch mud pipe is also provided, laid through from the front chamber to the outer line of the embankment.

CLEANING FILTER.

Provision is made to clean the filter from time to time, as may be required, without interfering with the supply to the distribution, as follows: A short 12-inch inlet cleaning tube is led from near the bottom of the outer chamber to a point directly under the centre of the base of the coke. A 12-inch waste pipe connecting by branch with the mud pipe is let in from top of the coke in middle chamber down to the mud pipe in third chamber. Two additional supply pipes are carried through from chamber No. 1 to chamber No. 3, to use to supply the distribution while the coke is being cleaned.

When the filter is to be cleaned the regular filter inlet tube is closed up. The additional supply pipe leading past the filter is opened, supplying the distribution independently of filter bed. The short 12-inch inlet cleaning tube is opened; the water then passes up through the coke, reversing the line of flow, thus freeing the coke from all the deposits, and the foul water is passed

off through the 12-inch waste pipe that leads from the top of the coke down to the mud pipe and thence out to the ground at the foot of slope of the bank. The coke may thus be cleaned as often as it is found necessary. I adopted coke as a filter material from its very favorable action on the microscopic living germs.

Mr. Percy Frankland, the well-known English analyst, has made some very exhaustive experiments, to determine the relative values of coke, animal charcoal, and other substances. (Proceedings of Institute of Civil Engineers, England, 1886.) He says:

"Until the method of water examination by gelatine culture was devised, there were no available means by which the relative efficiency, for the removal of micro-organisms of different filtering material could be estimated on a quantitative basis. The author has submitted to examination, as regards their efficiency in this respect, a number of filtering materials, employing in all cases equal thicknesses of the various substances which were also prepared in the same state of division. The results obtained in these experiments were:

Ferruginous green sand. Initial efficiency, organisms per cubic centimetre, before filtering, 80; after, none. Reduction per cent. 100. After thirteen days, before filtering, 8,000; after, 1000. Reduction per cent. 88. After one month's action, before filtering, 1,280, after, 780. Reduction per cent. 39.

Animal Charcoal. Initial efficiency, organisms too numerous to count before filtering: after, none. Reduction 100 per cent. After thirteen days action, before filtering. 2,800; after, none. Reduction per cent. 100. After one month's action, organisms before filtering, 1.280; after, 7,000. Reduction none; but an increase of 447 per cent.

Coke. Initial efficiency, organisms per cubic centimetre before filtering, 3,000; after, none. Reduction per cent. 100. After five weeks action, before filtering, 6,000; after, 90. Reduction per cent. 98½.

The author has made further experiments on the efficiency of coke as a filtering material. In these experiments the filters employed were of similar construction, but an aqueous extract of garden soil was employed instead of urine water. Two similar filters (a) and (b) were submitted to examination under conditions as similar as possible.

INITIAL EFFICIENCY (SECOND DAY).

Unfiltered water 26,000 organisms per cubic centimetre:

Filter (a)	none.
Filter (b)	none.

Reduction in both, 100 per cent.

After three weeks' action, twenty-first day:

Unfiltered water,	2.230 organisms.
Filter (a)	339 "
Filter (b)	219 "

Reduction (a)85 per cent. (b) 90 per cent."

Mr. Frankland's experiments show that with the coke filter properly attended to, it may be relied upon to do the work expected.

CONCLUSION.

I am satisfied that this system of water purification by aeration, using water ways or canals and a series of low dams, may be adapted to both gravity and pumping systems, and form a permanent, cheap and reliable method of improving the quality of potable water, and when once constructed it runs itself.

DISCUSSION.

The President. If there are any questions to be asked Mr. Babcock, the gentlemen are now at liberty to ask them.

Mr. FitzGerald. Is your water perfectly clear when you first take it?

Mr. Babcock. You may consider it is. It is a mountain stream and clear. Undoubtedly there is organic matter in it. At times after a heavy rain it is discolored some, and I have noticed that this canal precipitates these matters very nicely.

Mr. FitzGerald. Does the color come from vegetable matter? Is the water colored brown?

Mr. Babcock. I think it is. When we have a series of heavy rains in the spring and fall the water takes up a certain quantity of organic matter, vegetable matter, which discolors it.

Mr. FitzGerald. You have a series of sixteen weirs that the water passes over; is the water any clearer or any brighter after it passes over these weirs than it was before?

Mr. Babcock. Yes, the difference in the color is perceptible to the eye along the course of the aerating canal, as is also the precipitation in the bottom of the ponds. In the first one there is more deposit and it decreases to the last one. The last ones are almost clean, while in the first one there is considerable deposit.

Mr. FitzGerald. Have you had any analysis made comparing the water before it passes over these weirs and afterwards?

Mr. Babcock. No, sir, I have not had any yet, but I intend to have. I intend to have analyses made at the beginning of the nine mile conduit, at the end of the nine mile conduit, at the end of my aerating canal, and in the reservoir down town, but I have not had time to have it attended to yet. I have noticed, however, a very perceptible difference in the temperature between the water in the upper end of the canal and the lower end, which shows that there is oxidation producing heat. The temperature is higher at the lower end of the canal than at the upper end, and that shows there is a reduction of the impurities going on.

Mr. FitzGerald. That is very interesting. Have you tried the temperature of the water in the conduit just before it passes over the weirs?

Mr. Babcock. I have not tried that experiment yet, for my works are not quite finished. That is the last thing I intend to do. When my works are all completed, I shall have all these experiments made.

Mr. FitzGerald. I was wondering how you knew that oxidation produced the difference in temperature?

Mr. Babcock. I think so simply because oxidation always produces heat. I shall be very glad to make these experiments and submit a statement of the result to the Association. I think it may be of some interest.

Mr. FitzGerald. Yours are the only works where weirs are introduced in the conduit for the sake of aeration?

Mr. Babcock. It is the first time it has ever been attempted. I did intend to do it in the works at Amsterdam, but found it would cost about $60,000. Fortunately at Little Falls the ground was such that I built this portion of the works at a cost of about $16,000. I would have put it in at Amsterdam if it hadn't been so expensive.

Mr. FitzGerald. I am a little interested to know how you determined that the water was clearer after it passed over the weirs than it was before?

Mr. Babcock. It was apparent to the eye.

Mr. FitzGerald. You made no special examination of it?

Mr. Babcock. I have made no special examination as yet. I intend to have Prof. Dickey, of Utica, make a careful set of examinations. The works are not finished as yet. We are using the canal, but it is not fully completed.

Mr. Billings. You said the temperature of the water at the lower end of the open canal was higher than at the upper?

Mr. Babcock. Yes.

Mr. Billings. Do you know how much?

Mr. Babcock. I do not know how much, but it is quite perceptible. I haven't made any exact test of it.

Mr. Billings. How have you determined that there is a difference?

Mr. Babcock. By placing the thermometer in the water at the upper end, at the first dam, and then in the lower end you get a difference of two or three degrees.*

Mr. Billings. What is the depth of water in the canal?

Mr. Babcock. It carries about 4,000,000 gallons, and it runs eight or ten inches deep, with quite a velocity.

Mr. Billings. You wouldn't think the sun would heat it as it goes down?

Mr. Babcock. No, sir, there isn't time for it to do that.

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*It seems probable to us that the increased clearness is due to subsidence rather than oxidation, and that experiment will fail to prove an appreciable degree of heat to be caused by oxidation.—[Editor.

COVERED RESERVOIRS.

By Charles H. Swan, Civil and Sanitary Engineer,
Boston, Mass.

ANCIENT COVERED RESERVOIRS.

Covered reservoirs have been used for the storage of water, from periods of great antiquity. They have been constructed of various sizes and shapes, from the small cisterns supplying single dwellings, to the large reservoirs of ancient fortified cities, and of modern municipal water works.

During recent excavations at Jerusalem,* many ancient reservoirs have been discovered. Those which appear to be the oldest, and of very great antiquity, were formed by sinking deep wells through the rock and then making an enlargement at the bottom to act as a collector. Second in antiquity are the cisterns with natural roofs. These were excavated in a stratum of softer rock, the overlying harder stratum serving as a roof. A third class was formed by excavating the rock and covering the opening with an arch. A fourth class, modern, were built amid the loose debris, the accumulations of the centuries, which forms a large portion of the site of the modern city. It is estimated that the ancient subterranean cisterns in the vicinity of the Temple, alone, contained upwards of 10,000,000 gallons. One of them, known as the Great Sea, is said to have had a capacity of 2,000,000 gallons. Numerous other cisterns, some of them of large capacity, have been discovered, excavated in the rocky hills of the vicinity.

Although foreign to the immediate purpose of this paper, it may be interesting to mention a few facts relative to the ancient water supply of the city. Besides the water furnished by springs and wells, and by the collection of rain-water, there was a large supply brought from a distance by aqueducts. The remains of two such aqueducts are in existence; one the high level, the other the low-level. The latter was over 40 miles in length, and still carries water as far as Bethlehem. It corresponds in length with an aqueduct known to have been built by Pontius Pilate, but it cannot be fully identified. The high-level aqueduct drew its supply from a tunnel four miles long excavated in the rock beneath the bed of a valley on the road to Hebron. Near Rachel's tomb it crosses a valley by means of an inverted syphon, 15 inches in diameter, formed of large perforated blocks of stone set in a mass of rubble masonry. The joints seem to have been ground. They are united with an extremely hard cement. This aqueduct cannot be traced within some miles of the city, but it is supposed to have entered near the northwest corner and to have supplied the upper part of the city.

*The Recovery of Jerusalem. New York, 1871.

These brief statements, which are from the published accounts of the work of the Palestine Exploration Fund, show, as do the remains of Roman water works at Lyons, France, that the principles of hydrostatics were known to the ancients, who were prevented from applying these principles extensively, by the difficulty of obtaining, in those days, pipes of sufficient size and strength to convey large volumes of water under heavy pressure. The familiar arrangement of separate aqueducts under different heads for supplying high and low districts is also seen to date from a very remote period.

Many fortified cities of antiquity were provided with subterranean reservoirs to supply water during sieges. The ancient cisterns of Constantinople are reported to have contained a supply for 1,000,000 men during four months. Several of them are still in existence. Other ancient covered reservoirs might be mentioned, but these examples are sufficient to indicate their magnitude and importance.

MODERN COVERED RESERVOIRS.

The covered reservoirs of modern water works owe their origin to the necessity for maintaining the purity of the supply when it is stored in the vicinity of large cities. The effect of covering is:

1. To protect the water from solar heat and light; thereby securing uniformity of temperature and preventing the growth of vegetation.
2. To protect the water from atmospheric impurities.
3. To prevent malicious pollution.

These three classes of evils vary in relative importance in different climates and localities.

EFFECTS OF LIGHT AND HEAT.

It has for many years been recognized that water derived from certain subterranean sources is peculiarly liable to be invaded by vegetable growths upon exposure to the light and heat of the sun in open reservoirs. Examples of this action have been found in water from various geological formations, both in Europe and in the United States. Apparently, such water contains principles, which do not affect its clearness or limpidity, but which promote vegetation upon exposure to the light; rendering the water unsightly, and frequently developing a disagreeable taste and odor. The examinations of the water supplies of towns now being made by the Massachusetts State Board of Health will, it is hoped, furnish an explanation of this curious fact.

An interesting illustration of the effect of excluding sunlight from a water derived from subterranean sources, and which had caused complaint, is given by Mr. G. H. Parker in a recent report,* some of the details of which are as follows :—

*Massachusetts State Board of Health. Nineteenth annual report. Boston, 1888.

The town of Brookline is supplied with water from a covered filter gallery. The water is pumped into two reservoirs, one of which is an iron tank supplying the high service. Complaint having been made that the water supplied from these reservoirs had an offensive taste and smell, while the water in the filter gallery, which was in darkness, remained free from any disagreeable qualities, it was deemed advisable to cover the high service tank with a double roof, and ascertain whether the exclusion of light would prevent the development of the unpleasant changes.

Examinations made subsequent to the covering of the tank showed that while the water in the filtering gallery continued to be clear, free from green algæ, and devoid of disagreeable taste or smell, and while the water from the open reservoir continued to show "an abundant supply of green algæ, was slightly cloudy, and had a very strong taste and decidedly fishy smell," the water from the high service tank, "now completely darkened, contained only one specimen of green alga, was now free from odor and taste, and for all practicable purposes as good as that pumped at the filter gallery." It was concluded that the exclusion of light would be a complete remedy for the unpleasant effects, and the construction of a covered reservoir is contemplated.

Similar conclusions have been reached in England. Thomas Hawksley, the celebrated English engineer, testified in 1852 before the Select Committee on the Metropolis Water Supply Bill, that water taken from the new red sandstone was peculiarly liable to the growth of algæ if it was exposed to the sun, but that the exclusion of light and heat was a complete preventive. He also said that he had recommended covering a reservoir at Liverpool, a short time before, to avoid these unpleasant results.

The water of lakes and rivers may also be invaded by growths of algæ under favorable conditions. This growth is greatest in shallow open reservoirs, or ponds, where the water is comparatively still, and where it is exposed to a considerable elevation in temperature. In reservoirs exceeding 12 or 15 feet in depth the growth does not appear to be so troublesome.

ATMOSPHERIC IMPURITIES.

The danger of pollution from atmospheric impurities is greatest in the neighborhood of smoky cities. At London this was formerly the source of great annoyance. The surface of the water in reservoirs was often covered with a film of soot and dust, and if the water remained in the reservoir a sufficient time it acquired a bitter flavor.

The General Board of Health in its report in 1852 on the supply of water to the metropolis, in consideration of this trouble and also of the fact that filtered water after exposure in open reservoirs frequently had to be strained before it could be used for domestic purposes, on account of growths of algæ in the reservoirs, arrived at the following conclusion: "Against the modern engineering practice of exposed and open reservoirs we would rather revert to the custom of the Roman engineers and recommend covering the service reservoirs and aqueducts to the utmost extent practicable."

Influenced by similar considerations, the Select Committee of the House of Commons reported a bill, which was passed July 1, 1852, containing the following clauses: "Every reservoir within a distance in a straight line from St.

Paul's cathedral in the City of London of not more than five miles, in which water for the supply for domestic use of the metropolis or any part thereof is stored or kept by any company, shall be roofed in or otherwise covered over: Provided always, that this provision shall not extend to any reservoir the water from which is subjected by the company to efficient filtration after it is discharged from such reservoir and before it is passed into the mains or pipes of the company for distribution, or to any reservoir the whole of the water from which is distributed through distinct mains or pipes for other than domestic purposes, nor to any reservoir whatever the water stored in which shall be used exclusively for other than domestic purposes. * * * No water shall be brought or conducted within the metropolis by any company for the purpose of domestic use otherwise than through pipes or through covered aqueducts unless the same shall be afterwards filtered before distribution."

English engineers, having in mind the conditions obtaining in England, appear to regard protection against soot and dust as the most important point, although they by no means ignore the importance of pretection against heat and light.

French engineers, on the other hand, seem to consider protection against solar influences as the most important. This naturally follows from the fact that French cities are much less smoky than English cities.

The atmospheric conditions in the United States resemble those of France, although there are localities in this country which are as smoky as any in England. The need of covered reservoirs has been felt here for several years, especially since the use of ground-water as a supply, and the practice of filtering, have become common, and several have been constructed.

METHODS OF CONSTRUCTION.

A covered reservoir does not usually present any serious difficulty to the engineer. It should be built of materials that are durable and which are not liable to injure the quality of the water. Iron has been used for pillars, girders, or covering; but its use is to be avoided on account of its liability to corrosion. Small reservoirs may be covered with ordinary roofs or sheds; but these do not usually afford a sufficient protection against the heat. The best and most usual covering is of masonry or brickwork covered with a thin coating of asphalt to prevent the percolation of surface drainage, and by a layer of earth. The numerous covered reservoirs near London are mostly built in this way. It is usual to provide numerous ventilators.

The shape and constructive details are greatly dependent upon local conditions. The following types are common:—1. A circular reservoir covered with a flat dome. 2. A circular reservoir of larger size divided by circular walls into several annular compartments each of which is arched. 3. A rectangular reservoir divided longitudinally by straight walls into several compartments each of which is arched. 4. A reservoir covered by groined arches supported upon masonry piers. There are also variations of these types made by using iron. It is very common to make openings in the division walls thereby uniting two or more compartments. In some instances these openings are so extensive that the wall becomes virtually a series of piers.

It would extend this paper to unwarrantable limits to attempt a description of the details of reservoirs of these various types, but it will be interesting to give descriptions of two covered reservoirs recently constructed at Mulhouse, Germany, and of the two-story reservoirs of Paris, which consist of one covered reservoir superimposed upon another.

MULHOUSE. This city is situated between the source of supply and the hill upon which the reservoirs are built; the water being pumped directly into the distribution pipes.* Its topography requires a high service, as well as a low service system. The low-service reservoir is so placed that its bottom is 35.85 meters (117.6 ft.) and its maximum water level is 39.65 meters (130 ft.) above the mean level of the streets. The high service reservoir situated 50.88 meters (167 ft.) above the low service reservoir, furnishes water to a limited suburban district containing a population of only 130 persons; about one-third of the area of the high service district being cultivated as gardens. The upper reservoir is supplied by pumps from the lower reservoir. It has a capacity of 1800 cubic metres (475,000 galls.) which is the estimated maximum consumption for one day.

The low-service reservoir has a capacity of 10,000 cubic metres (2,640,000 galls.) which is about two-thirds of the maximum daily consumption. It is excavated in the earth, arched over and covered with earth. It is formed of two perfectly similar compartments, each being 38.6 meters (126.6 ft.) long and 35.2 meters (115.4 ft.) wide. The walls on the sides which receive the thrust of the arches have a thickness at the base of 2.5 meters, (8.2 ft.) reduced by steps to 1.35 metres (4.4 ft.) at the top. The walls on the other sides have a mean thickness of 1.15 meters, (3.9 ft.). The wall separating the two compartments is 2 meters (6.6 ft.) thick at the base and 1.5 meters (4.9 ft.) at the top.

The covering arches are cylindrical, and are built of brick and cement in circular segments of 5 meters (16.4 ft.) span and 1.2 meters (3.9 ft.) rise. They are 35 cm. (14 in.) thick at the springs and 23 cm. (9 in.) at the key. The intermediate walls which support the arches are themselves pierced with arched openings which allow communication between the different bays. The pillars which are left between these openings are of brick and cement masonry. The skew-backs are all of cut stone. The exterior walls are of rubble masonry laid in hydraulic lime and lined with brickwork. The bottom is formed of a bed of concrete of hydraulic lime 35 cm. (14 in.) to 85 cm. (33½ in.) in thickness, covered with a course of bricks laid on edge in cement. The faces of the walls and pillars, the bottom of the reservoir and the intrados of the arches are covered with a smooth plaster of Portland cement 2cm. (1in.) in thickness all the angles being rounded. The bottom has a grade of 0.002 towards the drainage openings. The extrados has received a covering of cement 3 cm. (1¼ in.) in thickness and has been covered with one meter (3.3 ft.) of earth. Drainage pipes are laid in the hollows of the arches to lead off the water of the soil. The walls on two sides are covered externally with a sloping embankment and turfed. The earth covering the top of the reservoir is cultivated as a garden, and is used as a public promenade. The interior of

*Bulletin de la Societe Industrielle de Mulhouse. Nov' 1887.

the reservoir is aerated by 27 ventilators emerging from the soil, and covered with caps of galvanized sheet iron, so arranged that nothing can be put in from the outside.

The influent pipe, which is also the effluent pipe, divides into two on reaching the reservoir, and each branch runs to the middle of one of the compartments. This arrangement is to facilitate the circulation of the water in the reservoir, whether it is flowing in or flowing out. A pipe 50 cm. (20 in.) in diameter, with a valve, passes through the division wall and permits a communication between the two compartments when desired. The depth of water is 3.8 meters (12.5 ft.). There is an overflow-pipe and a drainage-pipe in each of the two compartments. These pipes unite in a single one of 25 cm. (10 in.) diameter, outside the reservoir, discharging into a sewer, after passing a trap which prevents any emanations from the sewer from entering the reservoir.

All the pipes issuing from the reservoir pass through a chamber, in which are the valves. The facade of the structure forming this chamber is an Ionic portico in white stone, surmounted by a balustrade at the level of the top of the reservoir. The interior of the reservoir is entered by means of two circular iron stairs 1.4 meters (4.6 ft.) in diameter. To reach the top of the reservoir, in coming from the city, there is a stone stair case of several flights built in the slope of the embankment.

The high-service reservoir is also excavated in the earth and covered with a meter of soil. It is in two compartments of 16 meters (52.5 ft.) by 17.53 meters (57.5 ft.) each, which are divided into 4 bays 4 meters (13.1 ft.) wide by means of walls of brick and cement 50 cm. (20 in.) thick. These walls have openings 4 meters (13.1 ft.) wide alternately at their extremities so that the water being led to the side opposite that at which it will flow out, has to traverse all the bays before reaching the orifice of exit. Stagnation of the water is thus prevented. This precaution is necessary in a reservoir of this kind, where the quantity of water to be supplied is very small, and even nothing during several consecutive days. The least work of the pumps thus sets in motion all the water contained in the reservoir.

The walls forming the sides have a thickness of 2.50 (8.2 ft.) to 1.75 (5.7 ft.) meters, those of the ends 1.15 meters (3.8 ft.). The arches supported by the intermediate walls and by the longitudinal walls have a span of 4 meters (13.1 ft.), 75 cm. (30 in.) rise, 37 cm. (14½ in.) thickness at the springs and 23 cm. (9 in.) at the keys. They are in brick and cement. The bottom is formed of 30 cm. (1 ft.) of concrete and 15 cm. (6 in.) of brick on edge. The interior linings and the ventilators are like those of the lower reservoir. The division wall across the middle of the reservoir is 1.5 (4.9 ft.) meters thick throughout its entire height. The maximum depth of water is 3.5 meters (11.5 ft.).

The influent pipe, after having passed the gate chamber, crosses all the bays of the interior and ends at the opposite longitudinal wall, where it turns upwards by an elbow to the high water level. The effluent pipe is at the level of the bottom of the reservoir, but a pit 45 cm. (18 in.) deep is constructed at its inlet in order that it may not draw out any deposits which might have formed on the bottom of the reservoir. The four overflow and drainage

pipes unite in a single one of 15 cm. (6 in.) diameter, which discharges into a rivulet.

PARIS. Among the most notable, are the two-story covered reservoirs at Paris. This city derives its water supply from several distinct sources ; from the river water of the Seine and the Marne ; from the Canal de l'Ourcq ; from artesian wells ; and from springs. The waters from these different sources vary much in quality ; that from artesian wells and springs being the purest. Spring water is brought by the aqueducts of Arcueil and of Belleville, but mainly by the new aqueducts from the upper waters of the Dhuis and the Vanne. The former supplies reservoirs at Menilmontant and Belleville in the easterly part of Paris ; the latter supplies the reservoir at Montrouge in the southern part of Paris.

Reservoir of Menilmontant. This reservoir receives, in two separate parts, the water from the Dhuis, and the water from the Marne.* The capacity of the reservoir receiving the water from the Dhuis was fixed at 2.5 times the daily discharge of the aqueduct, or at about 100,000 cubic meters (26,400,000 galls.). It was not easy to find a suitable location for so large a structure at Paris. The high land on the right bank of the Seine is under-laid with formations of gypsum, and this material has been so extensively quarried that nearly all the land not built upon is wanting in solidity. After a long search, an undisturbed site was found at Menilmontant, but consisting of the worst material, the green clay of Montmartre. Solid foundations were reached at a depth of 6 or 7 meters (20 to 23 ft.) In order not to be obliged to purchase a separate site for the reservoir to receive the water from the Marne, it was decided to establish this latter in the spaces between the long pillars forming the foundation of the reservoir for the water from the Dhuis, by excavating the clay.

The reservoir of Menilmontant consists consequently of two stories, each of which is divided into two compartments. The two lower compartments, of a capacity of 28,500 cubic meters (7,500,000 galls.), receive the water from the Marne, raised by the pumps at Saint-Maur. Their overflow is at the elevation, 100 meters (328 ft.). The two upper compartments, of a capacity of 100,000 cubic meters (26,400,000 galls.) receive the water from the Dhuis and from the spring of Saint-Maur. Their over-flow is at the elevation, 108 meters (354.3 ft.) The useful area of the reservoir is 2 hektars (5 acres). Its cost was about 28 francs per cubic meter of useful capacity. It was begun in August, 1863. The water from the Dhuis was introduced into the reservoir in October, 1865, and the water from the Marne in January, 1866. The reservoir was most carefully constructed. Its failure would be attended with disastrous consequences, from its proximity to a dense population.

Some of the more important details of this reservoir are as follows :—†

The shape of the upper reservoir is a semi-circle united with a rectangle. The diameter of the semi-circle, which is 188 meters (617 ft.), forms the long side of the rectangle, whose other dimension is 42.5 meters (139.4 ft.). It is divided into two equal and symmetrical compartments by a division wall, following the radius perpendicular to the long side of the rectangle. The walls

*Belgrand. Les travaux souterrains de Paris. V 4.

†Debauve. Manuel de l'ingenieur des ponts et chausees, fasc: 16.

of the perimeter have a thickness of 1.4 meters (4.6 ft.) at the top. The interior batter is 1 in 5 for the portion of the wall below the earth. Above the surface the exterior face is vertical. The interior faces are vertical, but are joined with the bottom by an arc 2 meters (6.6 ft.) in radius. The bottom is formed by a system of semi-circular groined arches, for the part which covers the reservoir of the Marne, and in segmental groined arches for the other portions. The intrados of these latter rests upon the marl or clay. The arches are of rubble masonry, 35 cm. (14 in.) thick at the key. The reservoir is covered by groined arches, composed of two courses of bricks laid flat in cement. They rest upon pillars, 60 cm. (2 ft.) square and 6 meters (20 ft.) between centers. These pillars rest upon those forming the foundations of the bottom. The brick arches are about 8 cm. (3¼ in.) in thickness, including the plastering. They are covered by a layer of earth and turf, 40 cm. (16 in.) thick. The effluent pipes are 1 meter (39.4 in.) in diameter, and are so arranged that the supply may be drawn from either compartment or from the aqueduct. This reservoir may be emptied into that of the Marne, and its over-flow pipe, which is placed 5 meters (16.4 ft.) above the bottom, also discharges into the latter reservoir.

The reservoir for the water from the Marne occupies only the central portion of the sub-basement of the upper reservoir. Its form is a rectangle, whose larger dimension, parallel with the front, is 104 meters (341 ft.), the other dimension being 90 meters (295 ft.). It is divided into two equal and symmetrical compartments by the division wall above mentioned. The enclosing walls are placed in the middle, and follow the direction, of ranges of arches supporting the upper bottom. They are 1.2 meters (3.9 ft.) thick, with vertical faces; the interior face being joined with the bottom by an arc 2 meters (6.6 ft.) in radius. Their top forms a gallery, which allows free passage around the basins. The bottom follows the natural surface of the gypsum; its thickness being 30 cm. (1 ft.). The pillars which support the arches are 1.25 meters (4.1 ft.) square at the springs and 1.75 meters (5.7 ft.) at the bottom. The influent pipes are arranged to discharge into either or both compartments at pleasure. The effluent pipe is 80 cm. (31.5 in.) in diameter, and is so arranged that the supply may be furnished by either or both compartments. The walls are of rubble masonry. The interior surfaces are plastered with cement mortar.

Reservoir of Belleville. This reservoir* is situated, at a higher elevation than the one at Menilmontant, on the hill at Belleville. It is designed in two stories and four compartments, but only one-half has been constructed. The upper compartment of the capacity of 6,239 cubic meters (1,600,000 galls.) receives the water from the Dhuis. Its overflow is at the elevation 134.40 meters (441 ft.) The lower compartment is supplied by the water of the Marne ; its capacity is 11,765 cubic meters (3,100,000 galls.) and its overflow is at the elevation 131.10 meters (430 ft.)

This reservoir occupies a very threatening position. It is entirely above ground and is built upon a steep hill of fine sand. The greatest care was

*Belgrand, *loc. cit.*

taken in its construction. Standing upon such a foundation it is exposed to peculiar danger in case of accident, and the consequences of its failure would be incalculable. It was begun in September. 1863, and was finished in December, 1864. Including the residence of the custodians, it cost about 26 francs per cubic meter of useful capacity.

Reservoir of Montrouge. The capacity of this reservoir is 300,000 cubic meters (79,250,000 galls.) It was constructed on the same system as those at Menilmontant and Belleville, and cost about 20 francs per cubic meter of water stored. It is in two stories, each of which is divided into two compartments. The reservoir is rectangular and its details are similar to those of the reservoir of Menilmontant. It is supplied with water from the Vanne and contains about three times the average daily discharge of the aqueduct from that river.

GENERAL CONCLUSIONS.

The question as to the necessity of covering a reservoir must mainly depend upon local requirements and conditions. As a general guide it may be said that if the supply is from subterranean sources, or if it must be stored after being filtered, a covered reservoir is necessary, and that when a reservoir is amid smoky surroundings it should be covered. If the supply is from a river or lake, a covering is desirable, if the reservoir must needs be shallow. If the reservoir is deep, of large capacity, and not amid smoky surroundings, the necessity for covering diminishes and the question merges into one of cost. In the case of large storage reservoirs the expense of covering is generally prohibitory.

The best and most usual method of covering is by arches of masonry or brickwork, coated on the top with asphalt, and covered with two or three feet of earth, which may be turfed. Ventilation is important.

DISCUSSION.

The President. The subject is now open for discussion.

Mr. Allis. I should like to ask how the foundations were built for that reservoir which was placed on the sand?

Mr. Swan. The description of the reservoir I had access to did not go into details. The hill was formed of fine sand, which might have been wind blown, and although the details would be interesting, I am unable to go into them at present.

Mr. FitzGerald. I think we must have all enjoyed this paper on covered reservoirs, the subject is certainly one of great importance, and I believe it will attract more and more attention in this country as time goes on. I have always been, or at least for eight or ten years, an advocate of covered reservoirs for small supplies. I think, perhaps, the town of Brookline, which is now seriously considering the subject, will be the pioneer in the matter of covered reservoirs in this country. Certainly, there is great necessity in Brookline for something of the sort. I am sorry Mr. Forbes is not here, for he could tell you how serious the trouble with the water has been because of

the exposure to the air and light. Perhaps Mr. Swan can give us some statistics in regard to the cost per gallon of the reservoirs of which he has spoken in his paper. I think it was stated the cost per cubic metre was 26 francs, a little over five dollars. I should like to know if he has any other figures of the kind that he can give us.

Mr. Swan. The figures of cost are given in that way for the French reservoirs. The figures given for some English reservoirs are £5,000 per million gallons of useful capacity.

Mr. FitzGerald. There is another question I should like to ask the writer of the paper, and that is, if there are many of these circular reservoirs with annular spaces which are arched over, and also whether that is the favorite form of construction on the other side of the water?

Mr Swan. I only think of two and they are both in the vicinity of London. One is covered with rings of masonry arches, springing from wrought iron girders, bent into rings of great diameter and resting upon brick piers; and the other is covered with arches of hollow bricks resting upon iron beams, which reach from the centre pier to the sides. They were originally open reservoirs and were afterward covered.

Mr. Hawes. Does this covering of reservoirs interfere any with the aeration of the water? We have had a very interesting and convincing paper on that subject, and now we are told that we ought to cover the reservoirs. Isn't it necessary to have the sunlight in the aeration of the water, and don't the two things conflict? Here we have very strong arguments in favor of aeration and then arguments equally strong for covering the reservoirs.

Mr. Swan. The aeration of the water is provided for, to a certain extent, by means of the ventilating chimneys. The introduction of the sunlight would introduce a disturbing element, which would cause the development of vegetation, and neutralize the benefit which would be derived from covering the reservoir. I do not think the two things are necessarily to be associated.

Mr. Hawes. I would like to have Mr. Babcock's opinion on that.

Mr. Babcock. Aeration is a chemical process, and I do not see where the connection between the action of the sun and aeration comes in at all.

Mr. Hawes. Don't you get the heat of the sun in your aeration* process fully as much as any other element?

Mr. Babcock. No, sir; the heat of the sun is not necessarily an adjunct to a chemical process. Aeration would go on just as well in the dark as in the light.

Mr. Hawes. Would it be as purifying as in the sunlight?

Mr. Babcock. I think it would be better without the influence of the sun than it would with it. We know very well that subterranean sources of supply are considered pure, and the general conclusion is that it is due to aeration in this way: That the particles of air permeate the earth, and the water, in passing through it, takes up the oxygen, and the chemical process goes on.

*Evidently aeration is here confounded with oxidation.

Experiments by the English River Pollution Commissioners show that oxidation is most active in sunshine and almost ceases at night.—[Editor.

I do not see any connection between the action of the sun and aeration, which is purely a chemical process.

Mr. Tidd. I suppose it is a well-known fact among all who have anything to do with subterranean water, that it is more aerated than the water in streams and ponds. Those of us who have anything to do with the pumping of it know that we experience more trouble with it than with any other water, on account of the accumulation of air in the vacuum chamber. The water being so much aerated when it comes under the vacuum, that the air is extracted till it fills the vacuum chamber to such an extent that it comes through the pumps in bunches, and that is one of the worst obstacles we have to contend with. As Mr. Babcock says, I can see no connection between aeration and sunlight. My observation is that the water can be aerated in the darkest places that can be conceived of.

Mr. Babcock. I seem to have another ally to help me carry my point.

Mr. Rice. Isn't it questionable whether the means Mr. Swan speaks of as being adopted in the reservoirs he refers to for producing aeration are effective or not? He says it is done by means of chimneys. These chimneys are simply openings by which there is connection between the inner air immediately covering the surface of the water and the outer air of the atmosphere. Now, is there any way of producing the circulation of the air? Chimneys, it seems to me, are vents, but are they ventilators? They let the air in, but do they provide means to induce it to go in? Air simply in contact with the surface of the water is not going to mix to any great extent with the water itself. That can only be done by agitating the water, or by, in some manner, passing the air beneath the surface of the water, and then, by its own buoyancy, it will pass up through it, and thereby communicate or disseminate itself through the particles of the water. I do not see how the mere presence of chimneys can aerate the water.

Mr. Fitzgerald. The water taken from a filter gallery, as in the case of Brookline, of course we all know, is remarkably pure, and the main thing is to be able to deliver it to the consumer in the same condition. If it is exposed in an open reservoir it rapidly deteriorates, and the only practical way to obviate that is to have a covered reservoir, not too large in capacity, so that there can be a very quick circulation of the water in the reservoir. I suppose the necessity for aeration in such a case is comparatively small. It seems to me the only object of chimneys is to provide for a certain amount of circulation of air over the water. In regard to the question that Mr. Tidd has raised, which I think is an important and interesting one, as to the amount of air or oxygen combined with water in natural filter galleries, I would like to ask Prof. Drown, who has made a great many analyses throughout Massachusetts, if he has found that water from underground sources has more oxygen in it than water in open places has.

Prof. Drown. It has not been within the scheme of the analyses made under the direction of the Massachusetts State Board of Health to determine the oxygen in waters. I may remark that there is a little misconception with

regard to the aeration of waters and what it really means. If a water is perfectly pure, that is to say, contains no organic matter, there is no particular object, as I see, in aerating it; in fact, the aeration will generally take care of itself. If you agitate water it will take up the air rather more quickly than if it is only exposed on the surface, but at the same time, water that contained no air, if exposed to air on the surface without agitation would in time take up its due and normal amount. Now, if we have a ground water from which the organic matter has already been removed by filtration, and which is fairly well aerated, as many of such waters are, certainly shallow ones are, there would be no object while storing it in a covered reservoir to give it such access to the air. The amount of air that will remain in it is dependent upon the temperature; the higher the temperature the less air, the lower the temperature the more air. In aerating surface waters the idea is oxidation. If you have a surface water which is well aerated and perfectly pure, that is to say, reasonably free from organic matter, as the mountain stream would be, there is no need to aerate it, for there is nothing to oxidize. And that is what sanitarians and water experts generally mean by aeration of surface water. It has a purifying influence. If there is nothing to remove, if there isn't anything to purify, aeration has no significance, so far as I can see. The ground waters will hold an amount of oxygen dependent upon the temperature; the higher it goes up, as I have said, the less air there will be.

Now, when these waters get into open reservoirs, as has been explained before the Association heretofore by Mr. Stearns, it is there an entirely different matter. That is to say, the growths are probably dependent upon substances in ground waters which are not present in surface waters. I am somewhat in doubt as to the influence of the brown coloring matter in the surface waters, whether that prevents the growths which we find in the clear filtered waters when confined in uncovered reservoirs, and which is a matter of common observation. But, certainly, the nitrites which we find very largely in ground waters supply the food for the algæ, which grow and decompose, and probably to this cause is due the offensive smell in the waters that come from this source. Surface waters, when contained in large open reservoirs, of large capacity and of great depth, do not develop the class of odors which we associate with the uncovered reservoirs containing ground waters. I think this distinction ought not to be overlooked, that the disagreeable odor in ground waters in uncovered reservoirs is not that unpleasant odor, and has no similarity with it, so far as my experience goes, that we find in surface waters contained in large ponds.

Mr. Fitzgerald. If what Mr. Babcock has stated here is correct and aeration of the water by passing over weirs does remove the color, it is of extreme value to the profession to know it. It would certainly be a cheap way of arriving at a result which would be very desirable to all of us.

Mr. Babcock. In the case of my canal, we have a precipitation in the ponds as well as in the canal. Of coure, the influence of the oxygen upon the matter held in suspension creates a perceptible change in the precipitate.

The discussion was discontinued at this point, from want of time.—[Editor.

THE USE OF RELIEF OR SAFETY VALVES IN WATER WORKS DISTRIBUTION SYSTEMS.

BY

STEPHEN E. BABCOCK, Civil and Hydraulic Engineer,

Little Falls, N. Y.

GENTLEMEN OF THE NEW ENGLAND WATER WORKS ASSOCIATION:

In preparing a paper on the use of Relief or Safety Valves in Water Works Distribution Systems, the subject is so intimately connected with the weights of pipe used or to be used, that my paper must be largely devoted to it, in order to properly connect the use of safety valves on a distribution system, both to show the desirability of their use, the elimination of the water ram practically from the problem, the safe reduction in weights that may be depended upon, and the relative cost of safety valves as compared with the saving in first cost of pipe.

THEORETIC STRENGTH AND COMMON USAGE.

The construction and extension of water works systems has now become so general throughout this country that the question of weight of pipe to be used is being looked into more and more carefully, with every decade of years. That vast sums of money lay buried up in the ground in the shape of cast iron water pipe, made extra heavy, I think goes without the saying.

The paper read by Mr. A. H. Howland, C. E., a member of this society, before the American Water Works Association, at Boston, in 1885, as well as the paper by Mr. A. T. Noyes, C. E., read before this association at Springfield, Mass., in 1885, so clearly shows the formula upon which the theoretic strength may be determined, as well as the multiplicity and inconsistencies of standards which prevail throughout the country, that I will not waste your time repeating the data, but refer you to those papers. The cost of pipe is ordinarily about one-third the entire cost of any system of works, and should command the very careful attention of the constructing engineer.

HEADS AT LITTLE FALLS.

In designing the Little Falls, New York, water works, in the fall of 1885, where I am now engaged, I was confronted with a very hilly country. The only available site for a distribution reservoir was at an elevation of 540 feet above the town. The beginning of the distribution system started at an elevation of 250 feet, and ended 540 feet below the reservoir. Six years before, at Amsterdam, New York, I had resorted to the use of pressure valves, successfully, to cut down an excessive pressure of 135 lbs., to 100 lbs. I at once saw that I must use pressure valves to reduce pressure in this distribution system, which I determined to place at the 250 feet head point, and to cut out

200 feet, leaving me 50 feet at this point, or 340 feet head on the main portion of the system. But experience had taught me, that sometimes the full pressure gets on the system in spite of you, and, that sometimes, occurs too disagreeably often to make it at all desirable, or safe, to calculate the weight of pipe on the reduced head.

MANUFACTURERS' TABLES AND COMMON USAGE.

In determining upon the most desirable formulas upon which to base the standard weights of pipe, I found, first, that all the manufacturers' tables of weights stopped at about 300 feet head. The Warren Foundry gives safe weights for 50, 100, 150, 200 and 250 feet heads. R. D. Wood & Co., give 116, 230 and 300 feet heads. The Donaldson Iron Co., from 50 to 400 feet, and all the rest similar to the Warren, or 300 feet head. Now, all my distribution was embraced between the limits of 250 to 540 feet head, their tables, then, would only be a guide for a very small portion of the system, and an inspection of the tables showed that very heavy weights were called for. A comparison of the weights used in the various water works of the country, or at least such as I could obtain access to, showed that about 300 feet was ordinarily the limit of head of the various systems, and it also showed a multiplicity of standards, the very same state of facts to which Mr. Noyes' paper in 1885 calls attention.

FORMULAS.

The various formulas, as given by Meigs, Fanning, Shedd, Ranken, Weisback, Latham, Fairbain and some ten or fifteen others, as also the formula by Humber in his work on water supply, embrace such a wide latitude of coefficient of safety, that they almost cease to be any guide, particularly on the smaller sizes of pipe.

This set me thinking. I knew what the theoretic strength should be, taking iron at its strength as generally used, viz., 16,000 lbs. to the square inch. I have learned by experience of the imperfections of castings, cold shuts, unequal thicknesses, brittleness from chilling, and the many other defects, the provisions that must be made for careless handling, and lastly the most serious difficulty, the bugbear of all water works, the water ram, that more than stares you in the face. That there is a certain weight or amount of metal that must be used, known as the least weight that metal will run at without chilling in the mould when running, is also another factor. I also understand that it costs no more to mold and run a heavy casting than a light one, except the bare cost of the metal used, and that the metal itself is only a factor of about one-third that enters into the cost of cast iron pipe, ready for delivery. I can readily see that the result is that pipe founders desire as heavy weights as possible, and want an extra price for light pipe, and that it is to their interest to decry all attempts to lighten weights. Taking all these elements into consideration, excepting and excluding the water ram, and using a factor of safety over the theoretic strength as calculated, seemed, to my mind, to be the first step. This led me to looking into the nature of the water ram, and an inquiry if it was possible to counteract its effect with any appliance that would be reasonably cheap and effective.

NATURE OF THE WATER RAM.

Dr. Arnott, in his old but valuable work on Physics, lays down this proposition :—

"In a quantity of fluid submitted to compression, the whole mass is equally affected and similarly in all directions. A given pressure, therefore, made upon an inch of the surface of a fluid confined in a vessel, as by a plug, forced inwards, is suddenly borne by every inch of the surface of the vessel, however large, and by every inch of the surface of any body immersed in the fluid."

"This truth is of great importance, both from its explaining so many remarkable phenomena of nature and for the useful application of it in the arts."

The fact that the weight of one pound of water, or any other force of one pound similarly applied, may be made through the medium of extended fluid surface to produce a pressure of hundreds or thousands of pounds has been called the hydrostatic paradox, yet there is nothing in reality more paradoxical in it than that one pound at the long end of the lever should balance ten pounds at the short end ; indeed, it is but another means of balancing different intensities of force by applying them to parts of an apparatus moving with different velocities.

HYDRAULIC RAM.

Again the Hydraulic Ram Machine, so called, and probably from which the sudden increase of pressure in water mains takes its name, is only another application of the same general law as stated so clearly by Dr. Arnott.

To understand the construction of this machine, suppose an orifice is made through the embankment of a reservoir, of either standing or running water, say, at the depth of four to five feet below the surface, such orifice receiving one end of a cylindrical tube, say 20 feet long, the tube being formed of iron or other suitable material, and placed horizontal, or on a grade, as the case may be. To the end of the tube farthest from the reservoir, is adapted a piece of metal called the head of the ram; it has two orifices, fitted with valves, one valve closes by ascending, the other by descending. The orifice which has the ascending valve, and which is, in fact, the remoter orifice, permits the water to escape freely; the other is covered by an air chamber, which air chamber is pierced near the bottom on one side by a hole, to which a tube is adapted that is elevated to the height to which it is proposed to raise the water. The operation of the machine is as follows: When the ram is started, the valve in the remoter orifice is open; the water which flows through the tube leading from the reservoir will pass along with a velocity which will continue to increase until the impact of the water on the valve in the remoter orifice causes it to close; the motion of all the water in the tube is suddenly stopped; this produces pressure at once, which exerts itself on all parts of the tube, and consequently on the rising valve, which opening, permits a portion of the water to escape through it to the air chamber above. The instant this portion of water escapes, the pressure in the tube becomes annihilated, the remoter valve drops down, and the water runs again, until it has acquired velocity sufficient to close the valve again. This operation is

continued so long as the flow of water continues through the pipe from the reservoir. The portion of water which passes into the air chamber soon covers the lower end of the small tube leading from the air chamber, and then the air which is above the water in the air chamber, having no communication with the atmosphere, will be compressed if the machine continues to act, and its expansive force, increasing with the compression, will compel the water to move up the ascending pipe. Every time the remoter valve shuts, a report is heard similar to the stroke of a hammer, and it is, in fact, a blow. The question now arises, what is the weight of that blow in pounds, how much pressure does it exert on the pipe, and what must the area of the second or ascending valve be, to overcome the effect of the blow, by discharging a portion of the water?

I find from some experiments by Gen. Haupt, in 1866, where the head of water to ram was 8.812 ft.; diameter of drive pipe, 1½ inches; length, 15 ft.; diameter of delivery pipe, ¾ inch; length, 200 ft.; vertical height to which water was raised, 63.4 ft.; strokes of ram per minute, 170; quantity of water which entered the ram per minute, 3.31 gal., equals 27.73 lbs.; quantity raised, 48 cubic inches, equals 1.736 lbs. Hence the power expended per minute was 27.73x8.812 lbs.=244.35 lbs.; power per blow of ram, 1.43 lbs.; quantity of water raised per blow, 0.01 lb.; quantity of water expended per blow, 1.63 lbs.

Also another experiment at the Polytechnic School, Paris:

Head of water to ram, 5.88 ft.; diameter of drive pipe, 3 inches; length, 38 ft.; diameter of delivery pipe, ¾ inch; length, 100 ft.; head to which water was raised, 38 ft.; strokes of ram per minute, 42; quantity of water which entered ram per minute, 39 lbs.; quantity of water raised, 4 lbs.; power expended per minute, 229 lbs.; power per blow, 5 lbs.; quantity of water raised per blow, 0.09 lbs.; quantity of water expended per blow, 0.93 lbs.

APPLICATION TO RAMS IN WATER WORKS MAINS.

Now, applying all this data to the case of so-called water rams in water mains, it is evident that the magnitude of the blow is directly due to the size of the outlets and the consumption or discharge from the outlets, which are suddenly closed by shutting down a valve, hydrant, or other appliance.

It is also apparent that, as in the case of the hydraulic ram machine, an escape of water equivalent to a portion of the quantity of water being discharged, but suddenly arrested, will annihilate the pressure or blow. Now, if instead of the air chamber and its appurtenances we simply have a safety valve, set to the normal pressure of the system at the point where located, we have a perfect relief, or safeguard, from the ill effects of a water ram in its immediate locality. The only question, then, is to determine the size of the relief outlets; and whether to make it into a few, or to sub-divide it up into many, scattered throughout the distribution system.

The shutting down of the taps of a system is evidently controlled by the law of averages. For instance, on any water works system, particularly a large one, the law of averages would indicate that

there would be as many families opening up their taps as there are that would be shutting down; therefore one relieves the other. If we could so arrange it that all the taps of a water system were opened at one instant of time, the water allowed to acquire a velocity, and all shut down again at the same instant of time, we should have such a blow as no system could stand; but this can never occur, nor ever does occur, for one shut down is balanced by another opening, so that the ordinary domestic tap eliminates itself from the problem. Again, all well proportioned systems are calculated on the simultaneous use of ten hydrant streams. It is hardly probable that any contingence might arise that all would be shut down at once; but assume it; then it follows that if we have ten 2½-inch openings for relief, properly distributed, they would take care of the water ram. Again, it is possible, in a manufacturing city, that some of the mills might be shutting down at the same time as the hydrants; we must therefore make provision for this contingence. Again, a break may occur in a large main, and, through excitement, may be too hurriedly shut down. Taking all these contingencies into account, I hit on the plan of allowing one safety valve of three inches area to every mile of pipe in the system and one at each dead end, and conceived the idea of placing them at points of summit throughout the system and thick in the manufacturing districts.

BASIS OF FORMULAS FOR MAINS.

I then settled in my mind what seemed to me a tangible basis upon which to formulate the weight of pipe for the system, which was, to calculate the standard weights of pipe on the basis of one-tenth the tensile strength of cast iron, of 16,000 lbs. to the square inch, for the various heads, subdividing the system into three classes of pipe: A, 250 to 350 ft.; B, 350 to 425 ft.; C, 425 to 540 ft.; for all pipe larger than six inches; and use two classes for six-inch and four-inch pipe, viz.: A, 250 to 375 ft.; B, 375 to 540 ft.; and on the large feed mains and conduit, two classes: A, 0 to 150 ft; B, 150 to 250 ft., making the use of one three-inch safety valve to every mile of pipe and at the dead ends an adjunct or factor of safety.

My reason for preference in using one-tenth the tensile strength was this: My experience in connection with iron castings has taught me that, on the lighter weights as called for by the calculation, the thickness ran down too close to the limit at which iron will run well, to use any factor of safety less than one-tenth. The element of transportation or careless handling cracks, also inclined me to keep the safety factor up to one tenth instead of one-fifth A comparison of my weights with the manufacturers' tables, also with the weights used in very many of the large cities, showed that at one-tenth I was under either of them, except, perhaps, a place here and there.

RELIEF OR SAFETY VALVES.

In determining on the type of safety valves, I concluded to adopt the ordinary valve held down by a spiral spring, such as are generally used to relieve water pressure on railroad water columns. The more expensive pop safety

valves are more certain, perhaps, to respond to small changes of pressure, but are much more expensive, and, under certain conditions that may arise, more desirable. However, at Little Falls I adopted the common railroad valve. The cost was as follows:

20 3-inch safety valves, @ $12.50,	$250.00
Cost of setting, @ $10.00,	200.00
Total cost,	$450.00

The application or use of safety valves in a distribution system is not patented, and I am advised by patent lawyers that it is not patentable ; it is therefore free to all.

RESULTS AT LITTLE FALLS.

My standard weights, as formulated at Little Falls, are as follows:

SIZE.	CLASS.	HEAD.	WEIGHT PER FOOT.	WT. PER LENGTH.	Ultimate Breaking Pressure per Square Inch Iron, 16,000.	One-tenth Breaking Pressure per Sq. Inch.	Head Equivalent to One-Tenth.	LENGTH.	TOTAL WEIGHT.
					Pounds.	Pounds.	Feet.		
20	A	0— 50	120	1440	880	88	203	50	2.7
18	A	0— 50	112	1344	960	96	221	2352	354.49
18	B	50—150	125	1500	1140	114	263	4236	
16	A	0—100	98	1176	1100	110	253	7176	453.09
16	B	100—150	105	1260	1180	118	272	2952	
14	A	0—150	80	960	1165	116	268	3240	177.52
14	B	150—250	96	1152	1395	139	325	1404	
12	A	250—325	67	804	1335	133	315	2716	
12	B	325—400	87	1054	1735	173	425	10564	501.08
12	C	400—540	120	1440	2320	232	540	536	
10	A	250—350	52	624	1500	150	350	1783	
10	B	350—425	61	733	1735	173	425	2798	335.67
10	C	425—525	80	960	2240	224	526	6039	
8	B	350—425	42	504	1880	188	430	5363	357.72
8	C	425—530	52	624	2280	228	530	10843	
6	A	250—375	26	312	2025	202	475	9094	316.46
6	B	375—540	30	360	2340	234	545	15589	
4	A	250—375	17	204	2960	296	675	3194	164.42
4	B	375—540	18	216	3120	312	725	17143	

Total tons..... 2663.15

Cost at contract prices..... $84,476.03

The weight at manufacturers' lists, using their lists up to 400 feet, and proportioning balance at same ratio, would have been 3211.15 tons, costing at the Little Falls contract prices, $101,655.83. The difference in cost or saving was $17,179.80.

RESULTS AT LITTLE FALLS.

Theory always reads well, but the results of actual practice usually are more satisfactory to the average understanding. The actual results at Little

Falls have been very satisfactory. Last fall the safety valves were put to a very severe test, and demonstrated their utility. We have some five or six mills that are supplied with four-inch lines under 140 lbs. pressure; they are principally knitting mills; they use very large valves on their outlets, two, two and a half, and three inches. The greatest economy and best results in their washing machines are obtained by suddenly using all the force of the water pressure in their washing machines, and, as a matter of course, they shut off as rapidly. I have an Edson recording gauge in my office; the office is located on a large main line, and centrally with reference to the mills. The gauge runs as steady as a clock for weeks, without a variation of five pounds for a month at a time. I have the register taken, all on one slip of paper, for one month, showing this. The severe test, however, to which I desire to call your attention, occurred as follows: along in August, 1887, a break occurred on the main feed line, due to a transportation cracked pipe. It was promptly repaired. One of the caulkers, however, in cutting out the pipe, carelessly cut out a piece of pipe, 10x6 inches, and allowed it to fall into the next pipe. He said nothing about it; it was overlooked, and the break repaired, with this piece of pipe remaining in the barrel of the pipe. In course of time it traveled down the line until it reached the pressure valve landing there in November. It wedged the valve nearly closed. The result was the system was drawn out down to the 400 feet level, or about the upper mile wide cut out of the system. There was a normal pressure of 120 lbs. above the valve; the vacuum increased it 14 lbs. This broke the piston of the pressure valve, and it dropped down to a full port. This allowed a full column of water, two 12-inch pipes area, to descend down on the system, when the blow came back and followed up the feed line (where, unfortunately, I did not place any safety valves), it rammed out two lengths of pipe, but no damage was done whatever on the distribution system where the safety valves were placed. My gauge only indicated a few pounds above the normal total head, showing that the safety valves had done the work assigned them. I am now laying a second main feed line from the reservoir to the town, protected by two safety valves, and as soon as that is completed I shall place two safety valves on the other line. The original card of Edson recording gauge gives graphically a history of the ram and its effects upon the system where the valves were placed, showing no water ram. I desire to say, in passing, that the lines of fracture of the two pipes agree almost exactly with the tests made at Watertown for the city of Newton, which inferentially leads me to conclude that there was over 1,200 lbs. pressure to cause the rupture.

CONCLUSION.

I feel that the saving in first cost of pipe and the actual workings of the system, protected by safety valves, warrants me in bringing this matter to public notice through your associaton, and I desire to express my conviction that any system of pipe proportioned on one-tenth the tensile strength of cast iron of 16,000 lbs., and protected by safety valves, will eliminate all uncertainties of proper strength and do away with the disastrous results of water rams.

REGISTER OF THOSE IN ATTENDANCE

AT THE

PROVIDENCE CONVENTION, JUNE 13, 14, 15, 1888.

R. C. P. Coggeshall, Superintendent, New Bedford, Mass.
William R. Billings, Taunton, Mass.
Edwin Darling, Superintendent, Pawtucket, R. I.
Albert S. Glover, Water Registrar, West Newton, Mass.
J. A. Tilden, Hersey Meter Co., South Boston, Mass.
George E. Winslow, Superintendent, Waltham, Mass.
Edwin F. Pierce, Walworth Manufacturing Co., Boston, Mass
John C. Chase, Superintendent, Wilmington, N. C.
Charles E. Bolling, Superintendent, Richmond, Va.
Jesse Garrett, R. D. Wood & Co., Philadelphia, Pa.
J. E. Denton, Stevens Institute, Hoboken, N. J.
T. F. Hoezly, Hoboken, N. J.
S. E. Granniss, Superintendent, New Haven, Conn.
F. W. Shepperd, Fire and Water, New York City.
William Oliphant, Filters, 112 Liberty Street, New York City.
Henry Roeskeny, Gen'l Manager Philadelphia Water Purifying Co.
F. A. Peckham, Engineering News, New York City.
W. J. Harris, Edson Recording Gauge, New York City
Fred Adee & Co., 90 Beekman Street, Thos. J. Tracy, New York City.
J. H. Howland, 152 Grinnell Street, New Bedford, Mass.
W. H. Marsh, Tuerk Hyd. Power Co., New York City.
W. H. Richards, Superintendent, New London, Conn.
George F. Chase, Taunton Water Works, Mass.
D. B. Kempton, New Bedford, Mass.
Louis H. Knapp, Superintendent, Buffalo, N. Y.
Stephen E. Babcock, Chief Engineer, Little Falls, N. Y.
The Water Waste Prevention Co., 143 Nassau Street, New York City. T. I. Rae, representing "The Thompson Meter" and Water Waste Prevention Co.
John F. Philbin, Water Registrar, Clinton, Mass.
H. B. Winship, Norwich, Conn.
George E. Batchelder, Water Registrar, Worcester, Mass.
C. E. Peirce, Superintendent Fire District, East Providence, R. I.
Solon F. Smith, Superintendent Grafton Water Co., Mass.
Benjamin S. Terry, with A. W. Harris Oil Co.
G. B. Fitts, Superintendent and Registrar, Attleboro, Mass.
R. M. Gow, Superintendent Medford, Mass.
A. H. Salisbury, Lawrence, Mass.
Charles K. Walker, Manchester, N. H.
Thos. C. Lovell, Fitchburg, Mass.
Horace G. Holden, Nashua, N. H.

J. G. Tenney, Leominster, Mass.
W. B. Rogerson, Mansfield, Mass.
Charles H. Swan, Civil Engineer, Boston, Mass.
Joseph A. Lockwood, Yonkers. N. Y.
John C. Kelley, New York City.
Charles H. Baldwin, Boston, Mass.
F. H. Crandall, Civil Engineer, Burlington, Vt.
S. S. Coolidge, Bellows Falls, Vt.
A. W. Morgan, Buffalo, N. Y.
George J. Ries, Weymouth, Mass.
H. A. Nash, Jr., Weymouth, Mass.
Albert F. Noyes, City Engineer, West Newton, Mass.
William B. Sherman, Providence, R. I.
Phinehas Ball, Worcester, Mass.
Joseph E. Beals, Middleboro, Mass.
L. Fred Rice, Boston, Mass.
W. P. Whittemore, North Attleboro, Mass.
T. H. McKenzie, Southington, Conn.
William M. Hawes, Fall River, Mass.
W. N. Moulton, Union Water Meter Co., Worcester, Mass.
Fred A. Volk, Ware Water Works, Ware, Mass.
Willard Kent, Woonsocket, R. I.
Desmond FitzGerald, Boston Water Works, Boston, Mass.
Frank L. Fuller, Boston, Mass.
C. W. S. Seymour, Hingham, Mass.
William H Thomas, Hingham, Mass.
Parker Merrill, Melrose, Mass.
Hiram Nevons, Cambridge, Mass.
F. E. Hall, Quincy, Mass.
E. H. Phipps, New Haven, Conn.
C. F. Allen, Hyde Park, Mass.
Benjamin M. Earle, Providence, R. I.
George A. Stacy, Marlboro, Mass.
Ludlow Valve Manufacturing Co., by H. B. Winship.
William F. Codd, Nantucket, Mass.
H. W. Conant, Gardner, Mass.
H. N. Hyde, Jr., Newton, Mass.
William Gibson, Jr. New York City.
R. R. Yates, Northboro, Mass.
Dexter Brackett, Boston, Mass.
E. R. Jones, Boston, Mass.
F. P. Stearns, Boston, Mass.
J. W. Morse, Natick, Mass.
H. H. Goodnough, Boston, Mass.
W. C. Boyce, Worcester, Mass.
N. Dennett, Somerville, Mass.
E. E. Johnson, Worcester, Mass.
W. W. Robertson, Fall River, Mass.

Vacuum Oil Company, J. H. Wells, Boston, Mass.
Vacuum Oil Company, W. A. Root.
B. Frank Polsey, representing Walworth M'f'g Co., Boston, Mass.
John G. Brady, Worcester, Mass.
Solon N. Allis, Malden, Mass.
Melvin C. French, Kingston, Mass.
J. G. Whitney, Newton, Mass.
Benjamin S. Grush, Salem, Mass.
Robert J. Thomas, Lowell, Mass.
Weaver Osborn, Fall River, Mass.
Henry F. Jenks, Pawtucket, R. I.
R. A. Robertson, Jr., Providence, R. I.
A. G. Pease, Spencer, Mass.
Paul B. Patten, Salem, Mass.
Jason Giles, Indian Orchard, Mass.
Walter H. Foster, Boston, Mass.
W. F. Learned, Boston, Mass.
Joseph E. Watts, Lawrence, Mass.
R. D. S. Mortimer, Water Commissioner, Marlboro, Mass.
Miles F. Brennan, Lowell, Mass.
Charles L. Knapp, Lowell, Mass.
Henry Manly, Boston, Mass.
Harry E. Shaw, Lowell, Mass.
Edward H. Rice, Boston, Mass.

New England Water Works Association Membership Roll.

SEPTEMBER 1ST, 1888.

NOTE.—The secretary requests to be advised of existing errors or changes of address from that which appears in the following list.

ACTIVE MEMBERS—RESIDENT AND NON-RESIDENT.

Alexander, George
President Water Supply Co., Bath, Me. Address 70 Kilby street, Boston, Mass.

Andrews, Frank A.
Assistant Superintendent, Nashua, N. H.

Allen, Charles A.
City Engineer, Worcester, Mass.

Allen, Charles F.
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Babcock, Benjamin S.
Nashua, N. H.

Babcock, Stephen E.
Hydraulic Engineer, Little Falls, N. Y.

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Barns, Everett
Superintendent, Westerly, R. I.

Battles, James M.
Lowell, Mass.

Beals, Joseph E.
Clerk and Registrar, Middleboro, Mass.

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Brand, Junius A.
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Broatch, J. C.
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Chase, H. S.
Superintendent, Great Falls, N. H.

Chase, John C.
Superintendent, Wilmington, N. C.

Clark, Ezra
President and Superintendent, Hartford, Conn.

Clark, Jonas M.
Superintendent, Northampton, Mass.

Coburn, Walter
Lowell, Mass.

Cochran, Robert L.
Superintendent Water Works, Nahant, Mass.

Codd, William F.
Superintendent, Nantucket, Mass.

Conant, H. W.
Superintendent, Gardner, Mass.

Conant, Whitney
Secretary Water Co., Long Branch, N. J.

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Dotten, William T.
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Superintendent, Peterborough, Ontario, Canada.

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Hyde, Horatio N., Jr.
Superintendent, Newtonville, Mass.

Inman, A. W.
With A. H. Howland, C. E., 71 Equitable Building, Boston, Mass.

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New Brunswick, N. J.

Jones, R. A.
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Jordan, Nathaniel I.
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President Upper Appomattox Co., Petersburg, Va.

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Kieran, Patrick
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Martin, A. E.
Superintendent, South Framingham, Mass.

Martin, Cyrus B.
Treasurer Water Co., Norwich, N. Y.

Martine, Alfred H.
Superintendent, Knoxville, Tenn.

Mason, Marshall
Superintendent, St. Albans, Vt.

Maxcy, Josiah S.
Treasurer, Gardiner, Me.

McAllister, Willis E.
Superintendent, Calais, Me.

McClintock, W. E.
City Engineer, Chelsea, Mass.

Merrill, Parker
Superintendent, Melrose, Mass.

Molis, William
Superintendent, Muscatine, Iowa.

Morse, Charles W.
Superintendent, Haverhill, Mass.

Morse, James W.
Superintendent, Natick, Mass.

Murdoch, Gilbert
Chief Engineer and Superintendent, St. Johns, N. B.

Nason, William E.
Superintendent, Franklin, Mass.

Nettleton, Charles H.
Superintendent, Birmingham, Conn.

Nevons, Hiram
Superintendent, Cambridge, Mass.

Newton, Henry M.
Secretary, East Saginaw, Mich.

Noyes, Albert F.
City Engineer, West Newton, Mass.

Osborne, Weaver
Water Commissioner, Fall River, Mass.

Parker, F. H.
Burlington, Vt.

Pease, A. G.
Superintendent, Spencer, Mass.

Pengilly, Lewis H.
Civil Engineer, Tuxedo Park, N. Y.

Perkins, John H.
Superintendent, Watertown, Mass.

Philbin, John F.
Water Registrar, Clinton, Mass.

Phipps, Edward H.
Superintendent West Haven Water Co., New Haven, Conn.

Pierce, Charles E.
Superintendent, East Providence, R. I.

Pitman, Winthrop M.
Proprietor Water Works, Lower Bartlett, N. H.

Porter, James
Superintendent, Greenfield, Mass.

Ries, George J.
Superintendent, East Weymouth, Mass.

Rice, L. Fred
Civil Engineer, 4 Pemberton Square, Boston, Mass.

Richards, Walter H.
Superintendent, New London, Conn.

Ringrose, J. W.
Secretary, New Britain, Conn.

Robertson, W. W.
Water Registrar, Fall River, Mass.

Rogers, Henry W.
Agent for Maxcy & Lewis, Waterville, Me.

Rotch, William
Civil Engineer, 8 Exchange Place, Boston, Mass.

Russell, Daniel
Clerk Water Works, Everett, Mass.

Ryle, William
Superintendent, Paterson, N. J.

Salisbury, A. H.
Superintendent, Lawrence, Mass.

Schwenk, William
President Water Co., Mt. Carmel, Pa.

Seymour, Charles W. S.
Superintendent, Hingham, Mass.

Shedd, J. Herbert
Civil Engineer, Providence, R. I.

Sherman, William B.
Mechanical Engineer, Box 379, Providence, R. I.

Smith, Solon F.
Superintendent, Grafton, Mass.

Stacy, George A.
Superintendent, Marlboro, Mass.

Stearns, Arthur E.
Water Registrar, Manchester, N. H.

Stearns, Frederick P.
Chief Engineer, State Board of Health, 13 Beacon street, Boston, Mass.

Swain, George F.
Professor of Civil Engineering Mass. Inst. of Technology, Boston, Mass.

Swan, Charles H.
Civil Engineer, 25 Wabon street, Boston, Mass.

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Civil Engineer, with W. C. McClallan, U. S. Hotel, Boston, Mass.

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Thomas, William H.
Assistant Superintendent, Hingham, Mass.

Tidd, M. M.
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Constructing Engineer, Cohasset, Mass.

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Superintendent, Pierre, Dakota.

Truesdell, C. H.
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Superintendent, Ware, Mass.

Walker, Charles K.
Superintendent, Manchester, N. H.

Watters, Joseph
Water Commissioner, Fall River, Mass.

Wescott, George P.
Treasurer Water Co., Portland, Me.

Whitcomb, W. H.
President Water Co., Norway, Me.

Whitlock, Frank W.
Civil Engineer, Waterbury, Conn.

Whittier, Herbert F.
Water Registrar, Lawrence, Mass.

Wild, George E.
With A. H. Howland, C. E., 71 Equitable Building, Boston, Mass.

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Wilcox, William C.
Waltham, Mass.

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Civil Engineer, Norwich, Conn.

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Superintendent Water Works, Waltham, Mass.

Winslow, S. J.
Superintendent, Pittsfield, N. H.

Woodruff, Timothy
Superintendent, Bridgeton, N. J.

Yates, Richard R.
Superintendent Water Works, Northboro, Mass.

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Engineering News, Tribune Building, New York city.

Jones, E. R.
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Meyer, Henry C.
The Engineering and Building Record, 82 Fulton street, New York city.

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Fiske, Wilbur D.
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Chapman Valve Mfg. Co., Indian Orchard, Mass.

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Jackson & Woodin Mfg. Co.
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Langford, John T.
Contracting Engineer, 70 Kilby street, Boston. Mass.

Ludlow Valve Mfg. Co.
Troy, N. Y.

McClallan, W. C.
Contractor, U. S. Hotel, Boston, Mass.

McKenna, Thomas J.
Cast Iron Pipe, Equitable Building, 120 Broadway, New York city.

Marsh, W. H.
Tuerk Motor Co., 12 Cortlandt street, New York city.

Morgan, A. W., Mfg. Co.
Gates and Service Boxes, Buffalo, N. Y.

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National Meter Co.
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Agent Builders Iron Foundry, P. O. Box 218, Providence, R. I.

Root, W. J.
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Ross, George
Valves, Troy, N. Y.

Sampson, George H.
Powder, 231 State street, Boston, Mass.

Sumner & Goodwin
Pipe and Fittings, 21 Oliver street, Boston, Mass.

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Contractor, Woonsocket, R. I.

Tarr, H. G. H.
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Terry, Benjamin S. (A. W. Harris Oil Co.)
85 Hope street, Providence, R. I.

Equitable Water Meter Co.
33 India Wharf, Boston, Mass.

Edson, Jarvis B.
Recording Gauges, 145 Broadway, New York city.

Fiske, Wilbur D.
Knowles Steam Pump Co., 113 Federal street, Boston, Mass.

Frost & Adams
Architects' Supplies, 37 Cornhill, Boston, Mass.

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Engineers' Supplies, Pipe, etc., 36 Oliver street, Boston, Mass.

Gilchrist & Gorham
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Contractor, U. S. Hotel, Boston, Mass.

McKenna, Thomas J.
Cast Iron Pipe, Equitable Building, 120 Broadway, New York city.

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Terry, Benjamin S. (A. W. Harris Oil Co.)
85 Hope street, Providence, R. I.

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Turner, Clark & Rawson
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Woodman, George & Co.
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Gates and Hydrants, Granite, cor. First street, South Boston, Mass.

Worthington, H. R.
Steam Pumps, 86 Liberty street, New York city.